The American Journal of Surgery

NEW SERIES, VOL. XVIII DECEMBER, 1932 No. 3

DISCUSSION OF THE DIAGNOSIS AND X-RAY TREATMENT OF MALIGNANT DISEASE OF BONE*

SHERWOOD MOORE, M.D.

ST. LOUIS, MO.

MUCH of the substance of this paper is at variance with accepted views and will be disagreed with by many readers as it departs from orthodoxy at several points. The subject of bone tumors is far too obscure and unnecessarily so. It stands greatly in need of simplification.

The skeleton is a peculiarly suitable structure for investigation by *x*-ray methods. Since their advent into medicine, knowledge of the skeleton, its anatomy, physiology and pathology has grown enormously. The skeleton is far better understood than connective tissue, cartilage, adipose tissue, muscle, etc.

Of the diseases of bone, which have been most extensively studied, both on account of the great aid afforded by *x*-ray methods and because of their highly lethal nature, tumor has attracted much attention. Bone tumor has been for the past several years a popular subject for investigation and publication. Impetus to this arises from the work of the Registry of Bone Sarcoma of the American College of Surgeons. Credit for the notable accomplishment of this body should be given to Codman.

There are such authoritative publications on malignant bone tumors that any prospect of adding anything original to that which has already been written is almost out of the question. However, many physicians are unacquainted with this work. It will be the endeavor of this paper to direct attention to and popularize some of the excellent existing publications on malignant bone tumors with the idea of simplifying this obscure subject.

These publications are the studies of the material in the Registry of Bone Sarcoma of the American College of Surgeons by Codman[1] and Kolodny,[2] various publications by Bloodgood,[3] Ewing,[4] and Connor,[5] and the monograph of Geschickter and Copeland.[6] All of these are masterly. Nevertheless, it seems to a radiologist that there are certain points concerning bone tumors that these writers fail to develop. I wish to call attention to a significant fact, i.e., that these publications, with the exception of those of Ewing, were written by surgeons, and they necessarily lack the general view of the subject of gross bone pathology which one acquires in the radiological or pathological laboratory. This applies equally to matters of incidence, differential diagnosis and treatment.

INCIDENCE

The incidence of malignant bone tumors is not commensurate with the amount that has been written on the subject. The writings incline one to believe that malignant disease of bone, unfortunately too common as it is, is commoner than is actually the case. Furthermore, the more

* From the Department of Radiology, Washington University School of Medicine, and the Edward Mallinckrodt Institute of Radiology.

important publications have been made by men who have had an immense amount of accumulated material with which to work.

FIG. 1. Radiograph of hand made Nov. 5, 1928. Characteristic endothelial myeloma of third metacarpal bone. Excision of metacarpal.

One result of this condition has been the elaboration of classifications, etiological theories, and the promulgation of certain ideas in regard to treatment of bone tumors which are of theoretical rather than practical use. Unfortunately, the task of the physician or radiologist dealing with the occasional case of malignant disease of bone has not been made proportionately easier.

After all is said and done, the greater proportion of individuals with malignant condition in the skeleton will have to be cared for by what may be termed the casual radiologist or surgeon. All such cases cannot be put under the care of what may be termed specialists in the field of malignant bone disease. Except in those centers where special attention is paid to malignant bone tumors, and hence where many patients apply for treatment, their occurrence is fortunately rather rare. In

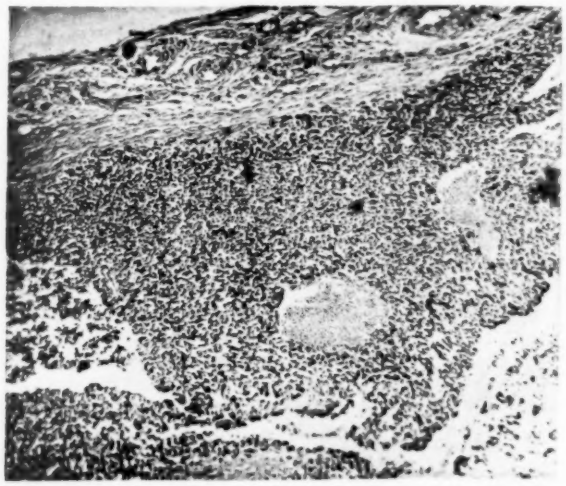


FIG. 2. Section of tissue near metacarpal taken at operation. Shows solid invasion of soft tissue by tumor cells. There is no intercellular substance and there is a tendency toward perithelial arrangement. There are several large blood spaces lined with tumor cells.

the hospitals allied to the Washington University School of Medicine, the Barnes Hospital, the St. Louis Children's Hospital, the St. Louis Maternity Hospital, in a period of eighteen years and in 123,285 hospital admissions there have been 220 cases of sarcoma with 96 examples of primary malignant bone tumors. Over the same period there were in the Barnes Hospital, 277 cases of secondary or metastatic malignant involvement of the skeleton in 5883 cases of carcinoma. The other tumors capable of skeletal metastasis have been too few in number and uncertain in diagnosis to warrant the labor of segregating them and forming an additional classification. The commonest sites of origin of these carcinomata were:

Alimentary tract	1214
Uterus	865
Breast	352
Prostate	234

The remaining cases were widely scattered among other epithelial structures.

The ratio of incidence of metastatic to primary bone tumor in the preceding statistics is 2.9 of the former to 1 of the latter. High as the figure is for metastatic bone tumor, I doubt if it shows the true incidence of that complication as such skeletal foci are not sought for as intensively as are the primary bone tumors. Systematic skeletal radiography in cancer would undoubtedly greatly increase the foregoing ratio. Our views of the secondary and remote manifestations of cancer are predicated on the findings in the autopsy room. These views should be modernized and brought into correct relationship with the facts as developed by radiography. It is not sufficiently well known how searching is radiography nor the extent to which it is capable of supplementing the knowledge attainable from the postmortem examination. In the vast majority of examples of metastatic bone tumors this unfortunate happening is of later occurrence in the course of cancer. With the increasing efficiency of treatment of cancer late manifestations are becoming more of a problem than ever before.

DEFINITIONS OF TERMS AND CLASSIFICATIONS

In view of this, some definitions of terms and a classification are in order, to secure an intelligent approach to the problem of differentiation of primary and metastatic skeletal involvement in malignant disease. This is an essential preliminary to the correct treatment of the cases with skeletal neoplastic disease. The classification and terms applied to *all bone lesions* by the Registry Committee of the American College of Surgeons is as follows:*

1. Metastatic tumors primary in tissues other than bone
2. Periosteral fibrosarcoma
3. Osteogenic tumors: (a) benign, and (b) malignant
4. Inflammatory conditions
5. Benign giant cell tumors
6. Angiomata: (a) benign, and (b) malignant
7. Ewing's tumor

Fig. 3. Radiograph of spine of Feb. 26, 1932. Arrow indicates destructive lesion in vertebra. Since first observation forearm amputated for local return of tumor.

8. Myeloma. (Among other omissions fracture and metabolic disease of bone!)

It should be said that in the radiological laboratory infectious processes, or their result in bone, offer great difficulty in differential diagnosis. Such differentiation is too lengthy to be included in the limits of this paper. Kolodny modifies the foregoing classification as far as it applies to primary malignant bone tumors as follows:

1. Osteogenic sarcoma
2. Ewing's sarcoma
3. Myeloma
4. A group of unclassified sarcoma, including among others angioendothelioma and extraperiosteal sarcoma.

This classification is admirable and it is especially applicable in the *x*-ray laboratory. It is also useful in the treatment of the diseases under discussion.

The writer differs with such an authority as Kolodny as to the classification of endothelioma of bone or Ewing's sarcoma, believing that it should be grouped with

* Taken from Kolodny, A., Bone Sarcoma. Chicago, Surgical Pub. Co., 1927.

the myelomas. Two of the cases observed by the author (Figs. 1–7), indicate by their course and spread that the tendency of

Fig. 4. Lateral radiograph of right leg of second case, April 3, 1929.

Fig. 5. Lateral radiograph of right leg, Aug. 23, 1929, showing characteristic effect of irradiation of Ewing's tumor.

endothelial myeloma is to the progressive involvement of the entire marrow with the formation of large osteolytic central tumors in multiple regions of the skeleton. In the writer's view they progressively involve the marrow system equally with the other myelomas. It would seem that the chief difference between endothelial myeloma and those of other type is that in the former the primary tumor attains a larger size at an earlier period than is the case in the latter, and, hence, attention is called to it sooner. In the published cases of endothelial myeloma there is remarkable paucity of reports as to the condition of the remainder of the skeleton at the time of discovery of the tumor. There is also a great lack of knowledge of the progression or course of the disease in a large group of cases. Myeloma of other type developing rapidly throughout the marrow system, and the tumors not attaining great size, does not come to the notice of the surgeon and radiologist until it is widespread. Apparently the reverse is true in endothelial myeloma; it is discovered earlier in its life cycle than the other myelomas.

In spite of the great merit of Kolodny's classification of the malignant bone tumors, it has seemed to the writer that this difficult subject could be further simplified by the following classification:

1. Tumors which originate from the tissues housed in bone. These are the various types of myeloma including endothelial myeloma (Fig. 8). Epithelial tumors of dental origin in the maxillae belong in this heading but are only mentioned. There must necessarily be a few rare tumors of blood vessel origin and malignant nature, angioendothelioma, etc., which belong in this class.

2. Bone tumor proper. Osteogenic sarcoma (Fig. 9).

3. Tumors originating from the invest-

Fig. 6. Anteroposterior radiograph of left knee joint of Oct. 8, 1929. Arrows indicate bone defects in femur and tibia. At this period there was a huge defect in the skull.

ments of bone, the periosteal fibrosarcoma, parosteal sarcoma, capsular sarcoma (Fig. 10). These last named are in no sense true bone tumors, except from the accident of juxtaposition. Only rarely do they involve, extend to, or infiltrate bone. They may, however, on occasion, cause resorption of bone which seems to be a pressure effect arising from their increase in size.

METASTASIS

Some remarks on the metastasis and spread of primary bone tumors are perti-

Fig. 7. Section from rib removed at autopsy. Pathological picture closely resembles that of Figure 2.

Fig. 8. Lateral radiograph of foot with characteristic changes in plasma cell myeloma in distal portion of a limb.

nent at this point.

In spreading, sarcomas follow the path of least resistance, and those of the skeleton are no exception to this rule. Osteogenic

sarcoma extends far beyond the limits which are demonstrable by *x*-ray or other methods of examination of the affected

Fig. 9.

bone. It has been shown that it may extend far up or down the marrow cavity. Large blood spaces develop in them, and these become invaded by tumor cells. Osteogenic sarcomas also follow to the limits of their extent the loose areolar tissue spaces in intermuscular septa, around blood vessels, etc. In the extremities it doubtless early reaches the point where the septa are fused into the dense fascias at the termination of the segments of limbs. When metastasis takes place, it is by a blood stream distribution of the metastatic material. Therefore, pulmonary metastases are the first to occur. This occurrence is of such constancy that it can be stated as a general rule in sarcoma. Sarcoma does not travel through the lymphatics, hence regional lymph nodes are usually spared.

Osteogenic sarcoma is rapidly invasive of surrounding soft tissues. Endothelial myeloma and myeloma are only slightly invasive when they break through the bone, and spread to adjacent tissues, the former more so than the latter. Pulmonary metastases are not found in the author's cases. Usually in the case of all types of myeloma, little if any of the tumor is found beyond the confines or immediate vicinity of the bone. Endothelial myeloma

Fig. 10. Radiograph of leg of Dec. 24, 1930. Large soft tissue tumor. Bone is unaffected.

FIG. 11. Radiograph of femora. Arrows indicate destruction of bone by metastatic nodules of hypernephroma.

FIG. 12. Radiograph of chest with characteristic findings of metastatic pulmonary sarcoma.

FIG. 13. Lateral radiograph of leg of Nov. 11, 1931. Case of Paget's disease. Arrow indicates destructive process at upper end of tibia.

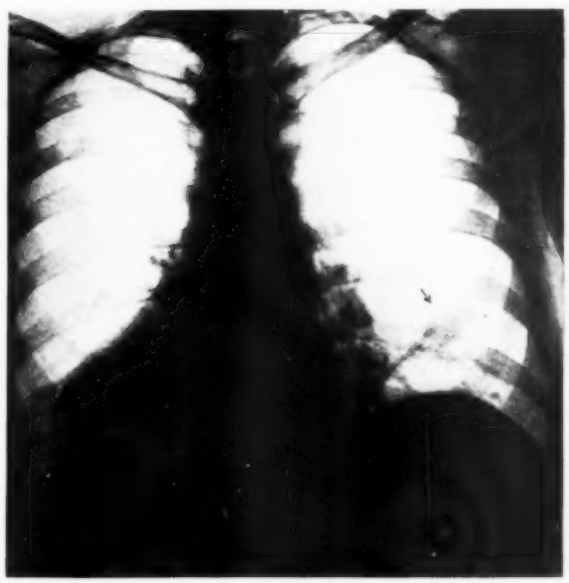


FIG. 14. Radiograph of chest of March 4, 1932. Arrows indicate areas of infiltration in lung thought to be a metastatic sarcoma from tibia.

while it may long remain a single focus is often said to metastasize to other bone. In the writer's opinion this merely represents a remote development of the same process in the marrow at a point distant from the first recognized growth. It is not a metastasis in the sense of embolic transport of malignant material from one point through the blood or lymph circulation to more remote ones elsewhere in the marrow.

FIG. 15. Photograph of gross material removed from tibia. White zone indicated by arrow was adenocarcinoma mocroscopically confirmed.

Extraperiosteal sarcoma, periosteal fibrosarcoma and capsular sarcoma are less distinctive in their radiological manifestations than osteogenic sarcoma. Their spread and metastasis apparently are the same as that of the soft tissue sarcomas which arise wholly independent of bone. I would condense the facts of the spread and metastasis of these tumors in the following way: Osteogenic sarcoma spreads rapidly into blood spaces and vessels (which it may form) along the areolar tissues, and for distances which cannot be suspected. It metastasizes by blood stream distribution and does not involve the lymphatics. The metastases are pulmonary. Endothelial myelomas and the other myelomas spread more slowly. Of these two groups only endothelial myeloma invades surrounding tissue to any great extent. All types of myeloma tend to involve ultimately the entire marrow system, with varying degrees of destruction of the containing bone. Extreme destruction of the marrow seems to be the cause of death. Myelomas do not metastasize as a general rule, certainly this is not observed in the *x*-ray laboratory.

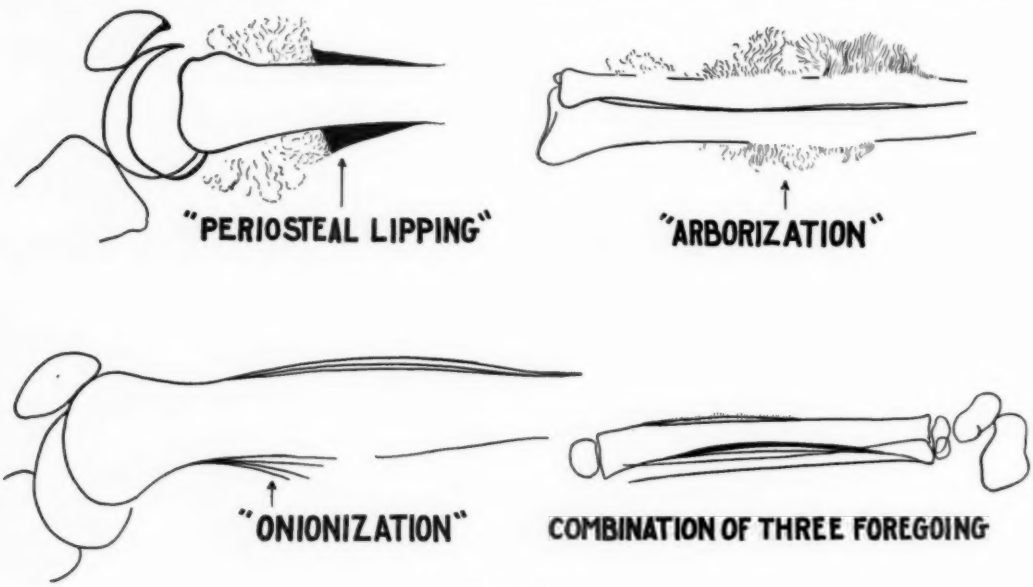


FIG. 16.

Sarcomas, either osteogenic or of other origin, only exceptionally extend to, that is, infiltrate adjacent bones or metastasize to remote portions of the skeleton. When bone metastases appear to be present the probabilities are that the tumor is of some other nature than sarcoma.

Fig. 17. Example of tumor and pathological fracture in which amputation is indicated.

Giant cell sarcoma must be referred to here because it has been so long put in the same category as the sarcomas. This disease can be considered as a malignant one only when it is neglected. Correct treatment removes it from the class of malignant diseases. Giant cell tumor is only slightly invasive of surrounding parts, does not metastasize and it only rarely recurs after excision or amputation if properly done, and does not directly destroy life. It is to be borne in mind, however, that malignant bone tumors sometimes contain giant cells, and lead to mistakes in diagnosis. The giant cell tumors will be referred to again when the therapy of malignant bone tumors is considered.

Metastatic hypernephromas cause much confusion in the diagnosis of bone lesions, and, hence, in treatment. They may form a single focus in a single bone, or they may have a wide distribution throughout the skeleton (Fig. 11) and at the same time the lungs may be the site of metastases. As far as radiological methods are concerned, they may simulate osteogenic sarcoma precisely both in their supposed primary focus in bone and in pulmonary distribution. They can also arise in younger persons which is not usually the case with the majority of the metastatic skeletal tumors. However, if there are multiple skeletal foci, and characteristic findings in the lungs, one may be safe in concluding that the case is not a bone sarcoma, but a hypernephroma.

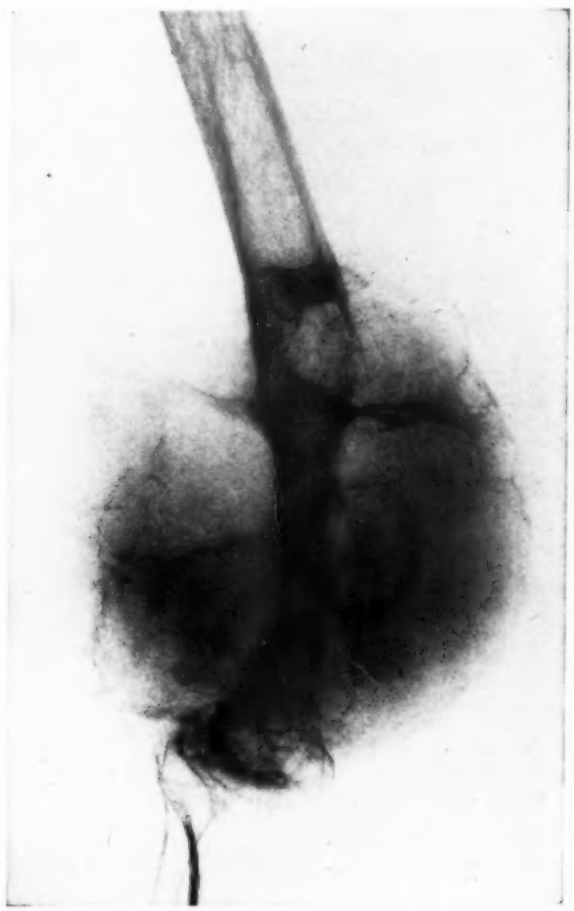


Fig. 18. Huge giant cell tumor too large for treatment other than amputation.

Epithelial tumors, metastatic to bone, have certain characteristics. Recognition of these aids materially in their separation

Fig. 19. Large parosteal sarcoma in which amputation is indicated. There is some evidence of pressure effect on posterior aspect of bone.

from primary malignant bone tumors. Obviously, the first point in separating primary bone tumors from epithelial metastases is that, in general, epithelial tumors will be found at a later age than is the case with sarcomas. If an epithelial tumor is metastatic to bone it is more likely to be multiple as to the bones involved. This is so contrary to the rule for bone tumor that it is a safe statement that multiple foci in bone eliminate primary bone tumor from consideration. Epithelial tumors so rarely metastasize distal to the most outlying lymph-node distribution, namely those at the elbow and knee joints, that it can be said that metastasis beyond these two joints is virtually never observed. Hence, a tumor arising in these distal segments of the limbs will not be a metastatic epithelial tumor. This particular behavior is also true of hypernephroma. Therefore, a tumor found in these locations must be primary in the bones involved and is either an osteogenic tumor or a myeloma. I will

Fig. 20.

digress enough at this point to say that in the examination of cases with actual or suspected bone tumor or metastasis that the entire skeleton be radiographed. This is a rule unfortunately more often observed in the breach than in performance. A radiological study in suspected cases of this nature is incomplete unless the chest is also examined.

Our material indicates that it is almost axiomatic that carcinomata do not metastasize to the lungs with the same manifestations as are found in sarcomas. That metastasis of the epithelial tumors to the lungs frequently occurs anyone with the

least knowledge of autopsy findings in carcinoma is well aware. This is most often by way of lymphatic permeation which

Fig. 21. Radiograph of knee joint, April 7, 1927. A giant cell tumor of inner condyle of femur.

does not produce the large globular growths (Fig. 12) in the parenchyma of the lungs usually found in metastatic sarcoma, or hypernephroma.

Bone sarcoma can occur late in life, but Kolodny (*loc. cit.*) is authority for the statement that 60 per cent of the cases reported have arisen on the basis of an existing Paget's disease. An example of such a case has been encountered which demonstrates that even so important a rule as this and the one of non-spread of epithelial tumors beyond knee and elbow joints, does admit of exception. (Figs. 13, 14 and 15.)

The spread and secondary manifestation of the other type of tumors in the skeleton and in the lungs have been too infrequent in the material studied to permit of any extended statement. Melanomas have never been noted metastatic in bone.

Fig. 22. Radiograph of same knee joint as in Figure 21, Dec. 7, 1929. Marked restitution and good function. Result of intensive *x*-ray treatment. Patient in satisfactory condition.

The majority of those arising in the skin seem to behave much as epithelial tumors do, and extend via the lymphatic system. Those from the nail bed and from the choroid seem to favor a blood-stream distribution to the parenchymatous organs. Tumors of the ovary and testes have been too infrequently noted in the *x*-ray laboratory and in character are too protean in their manifestation to permit of any general statement to be made concerning them

except that they destroy life before they involve the skeleton.

RADIOLOGY

It seems that those who write on bone tumors do so as if the subject were in a finished and complete state. The natural history of the disease, so to speak, appears to escape them. Because of this, overemphasis is put on certain things beyond their innate importance, while others are underestimated.

A radiologist can draw one conclusion in regard to much that has been written about bone tumors by those who are not radiologists. It is that instead of radiological findings contributing something essential to the final conclusion as to the condition in hand, that the history, gross pathology, and microscopic pathology are used to explain the *x*-ray findings. This is unfortunate, as unfortunate in fact as the case of the pathologist, who, given pathological material, must know the history, clinical course, etc., before he can venture upon an opinion as to the pathological material. Neither the pathologist nor the radiologist makes the final diagnosis. Their work is remarkably alike. Their service is to clarify and make certain, points in diagnosis and their function is to observe and interpret objectively material submitted to them for opinion. When the radiologist must have the complete clinical history before him, I am constrained to feel that his usefulness to those who have called upon him is at an end.

Writers on bone tumors are much given to stating that certain changes are pathognomonic of this, that or the other type of bone tumor. A small triangle of dense bone at the expanding portion of an osteogenic sarcoma has great importance paid to it as a diagnostic sign. "Arborization," i.e., the formation of fine lines of calcific material extending into the soft tissues, their course being perpendicular to the shaft of the bone, is also supposed to be pathognomonic of osteogenic sarcoma. The laminated structure in endothelial myeloma or "onionization" is also thought to be highly diagnostic (Fig. 16). The fact of the matter is, any of these three signs can accompany and do accompany conditions other than bone tumor. Single pathognomonic *x*-ray signs in bone tumors, either primary or secondary, are, in the writer's experience, non-existent. He feels that in the majority of instances an experienced radiologist can state the nature of a bone lesion with a correctness equal to that found in other medical opinion. However, he realizes his own incapacity to describe radiographic findings and likewise doubts the ability of others to do so. Identification of these conditions rests on the recognition of a congeries of physical changes in the involved bone, which elude description in words.

DIFFERENTIAL DIAGNOSIS

Unless the several malignant affections of the skeleton can be diagnostically differentiated, no intelligent method of dealing with them can be evolved. When confronted with the problem of a bone tumor it must be ascertained first whether it is primary or secondary. When this is achieved, what method of treatment is to be employed?

1. If the patient is a young person with involvement of the bones distal to the knee or elbow, and the tumor is single, we can assume that it is a primary tumor.

2. In the last condition, i.e., a single bone focus, proximal to knee or elbow joints, in a young person, and metastasis to the lungs, the condition may be either a primary bone tumor or a hypernephroma.

3. If there is a diffuse bone lesion involving many bones and indicating a centrifugal spread, one is not dealing with a primary bone tumor.

4. If one has a solitary bone lesion, even in view of a history of carcinoma or other malignant tumor, and there are round circumscribed areas of density in the parenchyma of the lungs, one is dealing with an osteogenic sarcoma or hypernephroma with metastasis in the lungs.

TREATMENT

In any bone lesion which is multiple, treatment resolves itself into the application of palliative measures. It is as a palliative measure that radiation therapy is of the most use. However, as it tends to lose its efficiency the longer it is applied, it should not be resorted to until symptoms are present. In other words, it should not be used as a placebo. Any skeletal lesion of the extremities which is definitely osteogenic sarcoma and not yet metastatic should in the opinion of this writer be treated with radical surgery, that is to say, that if the tumor is distal to the knee or elbow, amputation should be done, but, above the proximal joints. Osteogenic sarcoma of the humerus or shoulder girdle should have a shoulder girdle amputation. Since the spread of sarcoma may be of the nature pointed out earlier in this paper amputation at the hip joint for osteogenic sarcoma does not seem feasible, unless it be of the sclerosing type. The same statement is true of osteogenic tumors of the trunk, and in this field the writer believes that radiation therapy is the treatment of choice. Routine preoperative or postoperative radiation as a prophylactic measure in sarcoma has never had any special appeal to the writer and has only been given when requested by the surgeon.

In addition to the favorable response of endothelial myeloma to radiation and to the fact that there is ground for believing that it is a type of systemic disease it should be treated by radiation alone.

Where there are widespread metastases in osteogenic sarcoma, great pain, cachexia, etc., radiation should be applied. Pathological fractures of the extremities or great tumefaction, fungus formation, and ulceration should have in addition, and as a palliative measure, amputation or excision as the case may be, to be followed by radiation. (Figs. 17, 18, 19.) Surgery of this type has immense possibilities of affording symptomatic relief. It is not only justifiable but in the writer's opinion it is mandatory in those who suffer greatly. Not enough surgery of this type is done.

Secondary involvement of the skeleton with malignant disease presupposes, of course, widespread dissemination which makes surgical intervention quite out of the question on the face of it, unless it is palliative. These cases should be, and are, fit subjects for irradiation. It is the agency which gives them more relief, prolongs their lives, and contributes some degree of comfort. In the case of the spine there often is uncontrollable pain, even with morphine. Examples of relief from such pain by irradiation are within the knowledge of anyone with any material experience with the treatment of this type of case. Irradiation then is the symptomatic palliative treatment for widespread secondary tumors of the skeleton.

There have been enough examples of cure of giant cell tumor by irradiation that this agency should be the first choice in the treatment of these cases with certain exceptions. If irradiation after a reasonable trial fails to produce the desired result then one may resort to surgery. The exceptions are those where the tumor is of such great size and location that repair cannot be hoped for (Fig. 20). Irradiation should not be employed if a joint has been destroyed by the giant cell tumor and if recovery would result in a stiff flail or useless limb. In these last named conditions amputation is to be preferred. Admirable results are secured in giant cell tumor by irradiation alone (Figs. 21 and 22). It should be recalled that this tumor is not a common one, if it were there would be more cures reported.

The results reported by Coley following the use of his toxin treatment convince the writer that the toxin treatment of malignant bone disease should always be combined with the other methods of treatment.

What is to be expected from the treatment of tumors in bone? Of the myelomas with which the writer has had to deal a small amount of relief of pain has been

obtained almost immediately followed by development of secondary tumors elsewhere in the skeleton. The only example of osteogenic sarcoma that is known by the writer to have survived any method of treatment is one that he irradiated. This individual is alive nearly ten years after the development of the tumor. She was treated wrongly in every way. Amputation was recommended and refused. Biopsy was done, radium directly implanted into the growth, a proceeding at the time thought by many to be tantamount to destroying the patient. The implantation was followed by heavy *x*-radiation at intervals for months. The patient is well at the present writing. The case is reported elsewhere. All other cases of osteogenic sarcoma have been treated either in conjunction with surgery or the treatment started late in the disease, and all the patients of whom we have knowledge are dead.

It is possible that in some instances the reputed cures of Ewing's tumor by irradiation have been examples of osteogenic sarcoma. Color is lent to this belief by the fact that favorable irradiation response is often the basis for diagnosis of Ewing's tumor and, hence, biopsy is omitted.

None of the cases of metastatic tumor of the skeleton which we have treated has had a long survival. However, enough relief of symptoms has been contributed to make this procedure well worth while.

The first requirement for the successful treatment of a primary tumor of the skeleton is that all the tumor should be excised or all irradiated to secure a favorable result. Therein lies the explanation of all failures of treatment whether surgical or by irradiation. If the surgeon excises all of the disease the patient will be well. If the correct amount of *x*-ray be distributed throughout the tumor the patient will also get well. The fact that a tumor is secondary in one location, that is, metastatic, means that it probably has other undiscoverable extensions in other locations which it is simply impossible to recognize and to irradiate or remove. This is the chief reason for not irradiating secondary tumor of the skeleton in the absence of symptoms.

REFERENCES

1. Codman, E. A. Registry of Bone Sarcoma; 25 criteria for establishing diagnosis of osteogenic sarcoma; 13 registered cases of "five-year cures" analyzed according to these criteria. *Surg., Gynec., Obst.*, 42: 381–383, 1926.
2. Kolodny, A. Bone Sarcoma. Chicago, Surgical Pub. Co., 1927.
3. Bloodgood, J. C. Bone sarcoma periosteal and diffuse type, and their diagnosis from benign lesions. *J. Bone & Joint Surg.*, 8: 727–749, 1926.
   Bone tumors: sarcoma, periosteal group, sclerosing type, osteogenic, methods of diagnosis and treatment. *J. Radiol.*, vol. 4: 46–51, 1923.
   Bone diseases: non-suppurating osteomyelitis (Garré) infectious ossifying periostitis. *J. Radiol.*, 3: 310–316, 1922.
   Myxoma, central and periosteal. *Ann. Surg.*, 72: 712, 1920.
4. Ewing, J. A review and classification of bone sarcomas. *Arch. Surg.*, 4: 485–533, 1922.
   Neoplastic Diseases. Ed. 3. Phila., Saunders, 1931.
5. Connor, C. L. Endothelial myeloma, Ewing; report of 54 cases. *Arch. Surg.*, 4: 485–533, 1922.
6. Geschickter, C. F., and Copeland, M. M. Tumors of bone. *Am. J. Cancer*, 1931.

CHARACTERISTICS OF ADEQUATE ELECTROSURGICAL CURRENT*

A. J. McLean, M.D.

PORTLAND, ORE.

INTRODUCTORY

ELECTROSURGERY has reached its present stage of development almost entirely by an empiricism balancing between manufacturing agility on one side and clinical skepticism and daring on the other. Recent protest against claims of unstandardized and inadequate machines, comparable to patent medicines in lack of necessary available data concerning their physical characteristics and construction, has warrantably been made.[24]

Judging the subject too technical (or "super-scientific," as labelled by one council) for surgical inquiry, the medical profession, perforce, has had to be content to accept isolated and uncontrolled results as ultimate. Part of this lack of comparative criticism has been due to diffidence in the presence of a new technique, and part to lack of availability of varied apparatus and to lack of published material for wider comparison of performance. Beyond the initial impulse credited to Stoye by Maupin[14] and the pioneering close cooperation between Wyeth and a manufacturing firm's technical advisor, and between Bovie and the surgical staff of the Huntington (and allied) Hospitals, surgery, as far as recorded, has done little save to accept and try what has been presented as available. This paper records a series of data for several prominent American machines, and also attempts, through study of a flexible experimental construction, to rout some widespread misconceptions.

The electrosurgical unit, as utilized at present in major surgery, furnishes both coagulating and cutting currents. Recent wide adoption of modern devices has followed indeed upon the development of the latter, truly surgical, current. Coagulating currents, however, have long been known, and various modalities of high-frequency oscillations have been used in the treatment of both surgical and non-surgical conditions for almost half a century.

In 1881 Morton described before the New York Academy of Medicine the production and effects of induced static current.[16,17] In 1882, the physicist d'Arsonval did the same for d.c. low-frequency sine waves of various forms,[1] and nine years later reported similarly on alternating currents of frequency from two thousand to two billion per second;[2] two years later he reported heating effects in an electrostatic field within a giant helix;[3] meanwhile Riviere had used d'Arsonval currents for fulguration of intractable ulcers.[21] In 1907 Nagelschmidt reported on the indications and use of low-density high-frequency currents since known and utilized as diathermy.[19] In 1909 both Pozzi[20] and Doyen[9] detailed the use and technique of d'Arsonval currents for destruction of neoplastic tissue, and there began the dizzying differentiation and futile nomination of varieties of electrocoagulation, of which Clark's desiccation[7] alone is warranted clinically as a definite entity. Though Stoye's cutting current was created on a spark-gap machine producing damped waves (Fig. 1), gap construction for a time gave way to thermionic tubes (radio then being high novelty) and the peculiar idea of special physiologic qualities inhering in undamped cutting waves became propagated. In certain classes of work endothermic currents have such manifest advantages for dissection and hemostasis, over older methods that enveloping their

* Submitted for publication February 16, 1932.

modus operandi with hesitant and substantially unreal mystery, in the face of already known facts, can only be deplored.

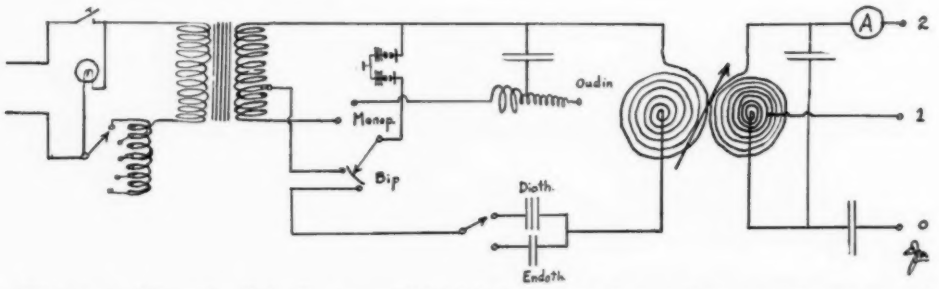


FIG. 1. Diagram of Stoye's clinically successful high frequency damped wave spark-gap endotherm.

The recorded early history of cutting currents is at present singularly obscure, and is contained only fragmentarily in footnotes and unearthed in chance discussions. In 1904, a Dr. Cohen unsuccessfully attempted a surgical operation at the Moabit Hospital, Berlin, with a damped cutting current machine devised by deForest. In 1907 deForest obtained his epochal patent on the triode tube. The following year he asked Weil and Sternberger at the Loomis Laboratory (Bellevue Hospital, New York) to undertake a few experimental operations with a cutting current machine he had devised utilizing the new tube; operations were successfully carried through on dogs. The device was also subsequently used there by Edwin Beer,[4] but deForest "never produced a machine which we could use" clinically. As already stated, Maupin attributes to Mr. K. Stoye, an electrical engineer, the production of the first successful cutting current, in 1918, presumably in Germany; I have been unable to confirm this in the literature or in personal communication with Stoye. Several American commercial concerns devised cutting current machines (1919–1923) whose results (because of unreliability, inexperience, burns, secondary healing, etc.) were such that widespread clinical adoption did not occur. It has been stated that in 1923 first applications of triode tubes to cutting were made in Germany, but the Loomis Laboratory machine antedates this by fifteen years. I have so far been unable to find substantiating data for the claim for Germany in a search of the literature.

In 1923 George A. Wyeth became interested in working with high-frequency currents in the old Loomis Laboratory and, in conjunction with the research department of an eastern electromedical concern, devised and in May, 1924 described[27] a successful* triode undamped cutting current machine; it could also deliver selectively to the same electrode a d'Arsonval coagulating current. Stoye, who withdrew from the eastern concern, independently devised in 1924 the first successful† damped cutting current machine. Both Wyeth's and Stoye's machines were exhibited at the Atlantic City A.M.A. Convention of May, 1925. Of the subsequent flood of somewhat crude damped cutting machines (outgrowths of the old diathermic devices), that of a midwestern concern was persistently improved by the biophysicist Bovie, and, combined with a coarser gap current optionally deliverable to the same electrode, has been the popular van of electrosurgery's spread in this, and some foreign, countries.

To Wyeth, therefore, belongs credit for the first clinically successful undamped current endotherm, and to Stoye for the almost simultaneous, and first clinically successful, damped current endotherm.‡

*Two tube self-rectification.

† Spark gap firing for 85–90 per cent of each half-wave of the alternating cycle.

‡ "Endothermy," despite objections, is a suitable and useful term[26] to distinguish surgical high-frequency currents from medical high-frequency currents.

Electrosurgical (and diathermic) high-frequency currents at present range from about 200,000 oscillations per second to 4,000,000; neither physiology, physics, nor mathematics affords present ground for suspicion of unusual or cryptic effects within this frequency band. In the upper ranges of the band, and in frequencies above it, conduction delivery of current, necessary at present in electrosurgery,

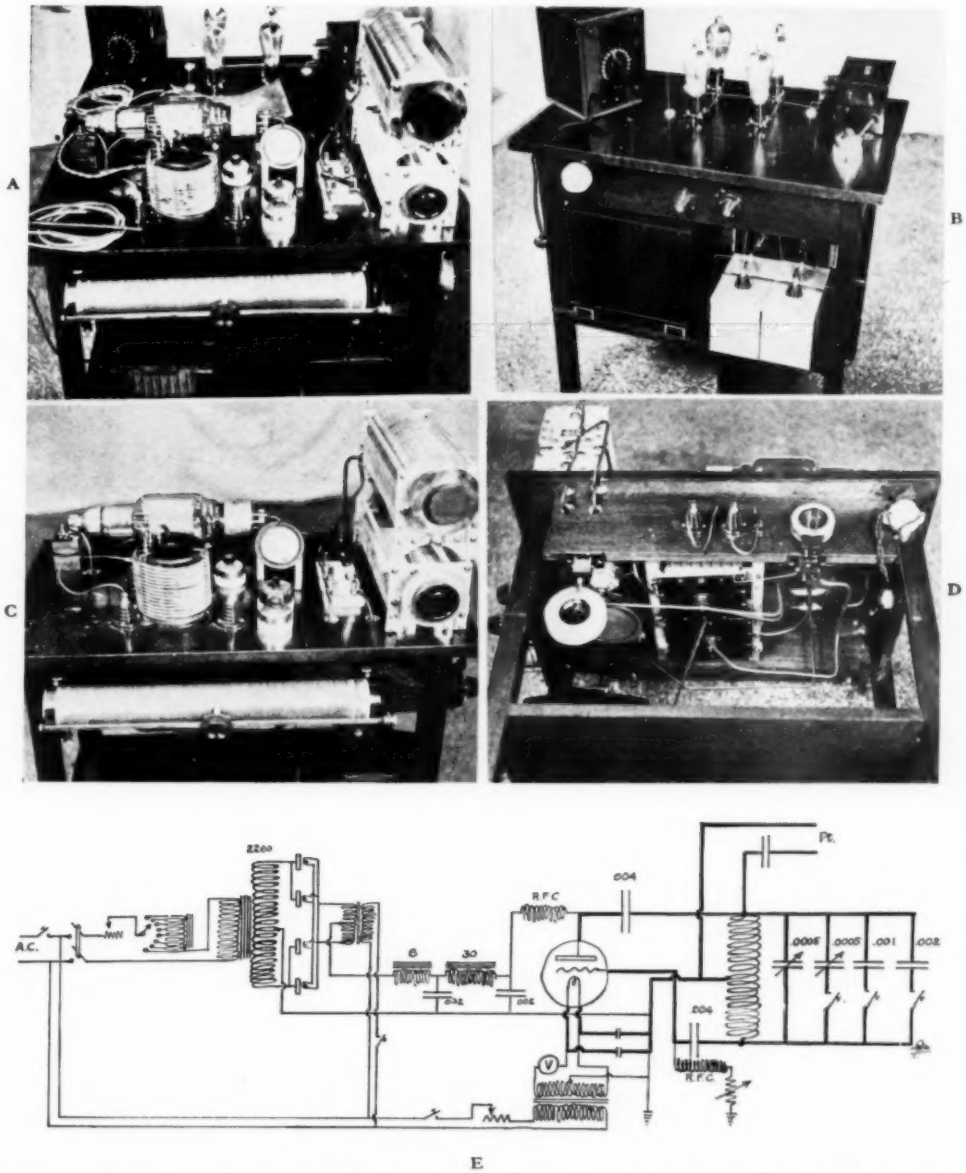


Fig. 2. Experimental unit constructed for this investigation. A. Assembled unit. B. Power table, where commercial alternating current at 110 v. was converted into direct current at 2200 v., and input to radio-frequency table controlled. C. Radio-frequency table, where direct current power was converted into oscillations ranging from 270,000 to 4,600,000 per second; variable condensers on right; radio-frequency coil, and triode tube, on left; sliding resistance for power, and variable resistances for grid leaks, are on sides of table. Knife switches key-in tuning condensers; turn switches control low-frequency power input, high-frequency power output and filament transformers; sliding resistance is supplemented by selective reactance shown on power table. D. Under side of radio-frequency table, showing fixed tuning condensers, protective condensers, and radio-frequency choke coils. E. Wiring diagram of experimental unit.

becomes increasingly difficult due to standing waves and power losses in cables of clinically necessary length (7–9 feet).

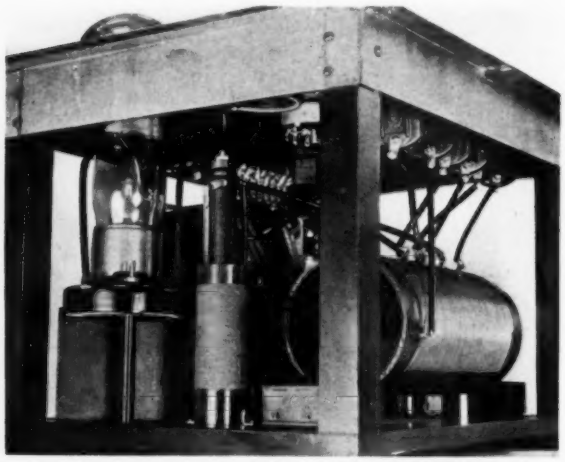


Fig. 3. A. Commercial triode machine B, showing one of power tubes, low-frequency transformer, resistances, choke coil, fixed tuning condensers and radio-frequency coil with taps and protective condensers.

Christie and Loomis,[6] however, demolished this by production of new evidence and by reinterpretation of Schereschewsky's results on a simpler basis of non-specific heat production. Hosmer[11] found in the lower reaches of this band some apparent selective heating effects of different frequencies upon various concentrations of saline solution. Woodbury[25] reported that Whitney, using about 50,000,000 frequency and about 200 times the power input utilized by Schereschewsky (7.5 watts), uncomfortably raised the temperature of nearby workers, cooked organic substances on neighboring antennae, and heated copper bars sufficiently to burn the hand when picked up; Bell and Ferguson[5] however reported that prolonged exposure to superhigh frequency radio current under service conditions was substantially negligible, though describing an interesting series of

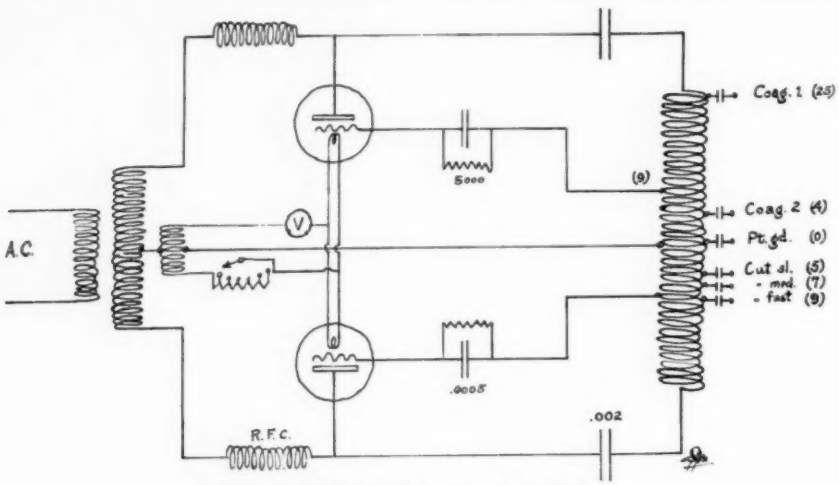


Fig. 3. B. Wiring diagram of machine B.

Electrostatic "conduction" however, involving niceties of resonant tuning (and stability and balance), has been studied by Schereschewsky[22] from 7,000,000 to 135,000,000 oscillations per second. Schereschewsky[23] in 1926 and 1928 believed he found a specific lethal frequency band ranging from 18,300,000 to 68,000,000, and, basing his interpretation on Lamb's mathematical work[13] for properties of elastic spheres, postulated for this band a form of destructive electromechanical vibration in cells of diameters from 7 to 96 microns. subjective and sensory phenomena derivable under special conditions. Beyond those frequency bands lie zones for heat; for infra-red, visible, and ultraviolet light; and for radioactive (*x*-ray and radium) oscillations.

Electrosurgery (endothermy) utilizes the production of intense local heat within the tissues; the intensity varies with current density. If the intensity is less than destructive, the current is conveniently called diathermic. In order to assure that heating effects only are produced, high-frequency

currents are used. One electrical stimulation per second of nerve or muscle causes an individual twitch in muscle; at 15 per second response is clonic; at 40 the muscle is in tetany and nerve trunk stimulation painful; above 2500 pain begins to diminish, but neuromuscular response remains maximal until 5000 and then decreases to 10,000; responses, other than development of heat, have vanished at 15,000. Modern electrothermic devices use frequencies from 80,000 to 4,000,000 and at such frequencies large amounts of electrical energy may be passed safely through the body without eliciting other than heating effects. This at present is the all-important and sole utility of high-frequency current as such. Cutting and coagulation have no fundamental bearing on frequency, oscillations, or wave form, contrary to current conception, and electrosurgical high-frequency is employed solely to assure the current's safe passage through the living body.

Electrical production of heat is dependent on quantity of current and amount of electrical resistance; in general it can be said that resistance decreases as frequency increases. If the resistance is encountered in the instrument through which the current is applied the instrument becomes hot, as in the electrocautery, where the current encounters resistance in the special wire tip of poor conduction properties, causing it to glow white hot (here the low-frequency current direct from lighting circuits is prevented from producing bodily harm by passage through a transformer, increasing amperage, but decreasing voltage below

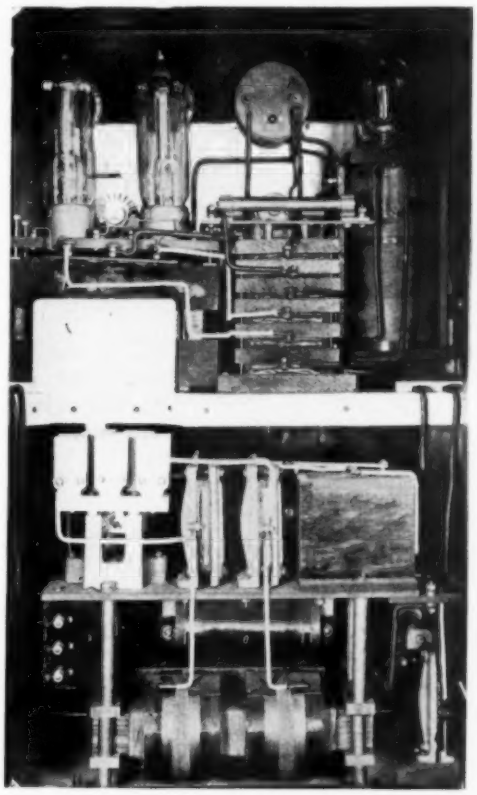


Fig. 4. A. Commercial triode and gap machine C. Cutting unit (triode) above and coagulating unit (gap) below; triode power tubes sit above low tension transformer and reactance; grid leak resistance is above bank of condensers, and neon lamp above radio-frequency coil and variocoupler. In lower unit vaned spark gaps, condensers, and Oudin coil sit above transformer and reactance.

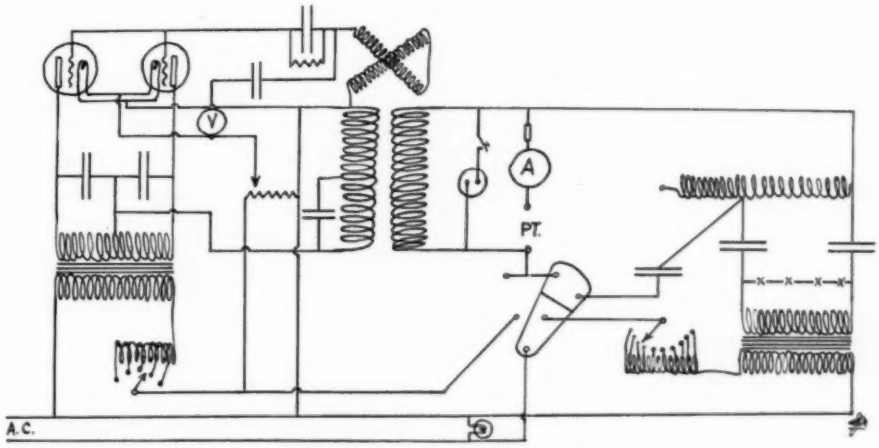


Fig. 4. B. Wiring diagram of machine C.

physiological stimulation range, the current's force being insufficient to produce direct physiological response). If the electrode tip be a good conductor, as in electrosurgical devices, the greater resistance is encountered within the tissues, and the heat is produced within the latter. In both, though the current is not painful, the heat is, and sensitive structures therefore must antecedently be anesthetised in a conscious subject.

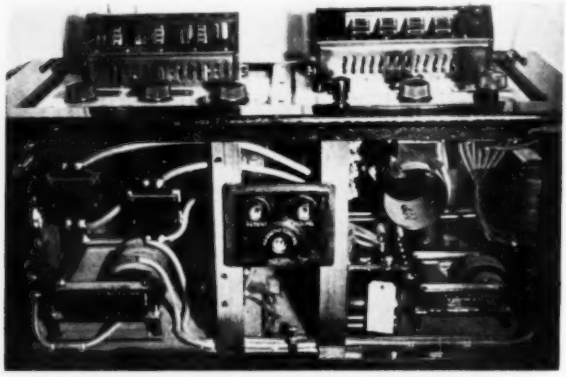


FIG. 5. A. Commercial gap machine D, cutting unit to left and coagulating unit to right. Micrometer spark gaps and dials above; transformers, coils, reactance, variocoupler and condensers below.

What effect the heat has is dependent on its intensity, and this in turn is electrically dependent on current density. A proper volume of current passing through the body between large (say, 8 inches square) electrodes is of low density, mildly warming, and not destructive, as in diathermy.[12] The same volume of current passed between a large and a small (say ¼ inch square) electrode produces a higher density at the smaller electrode, and coagulation of tissue ensues at the small electrode. That same volume of current passed between a broad electrode and a needle electrode

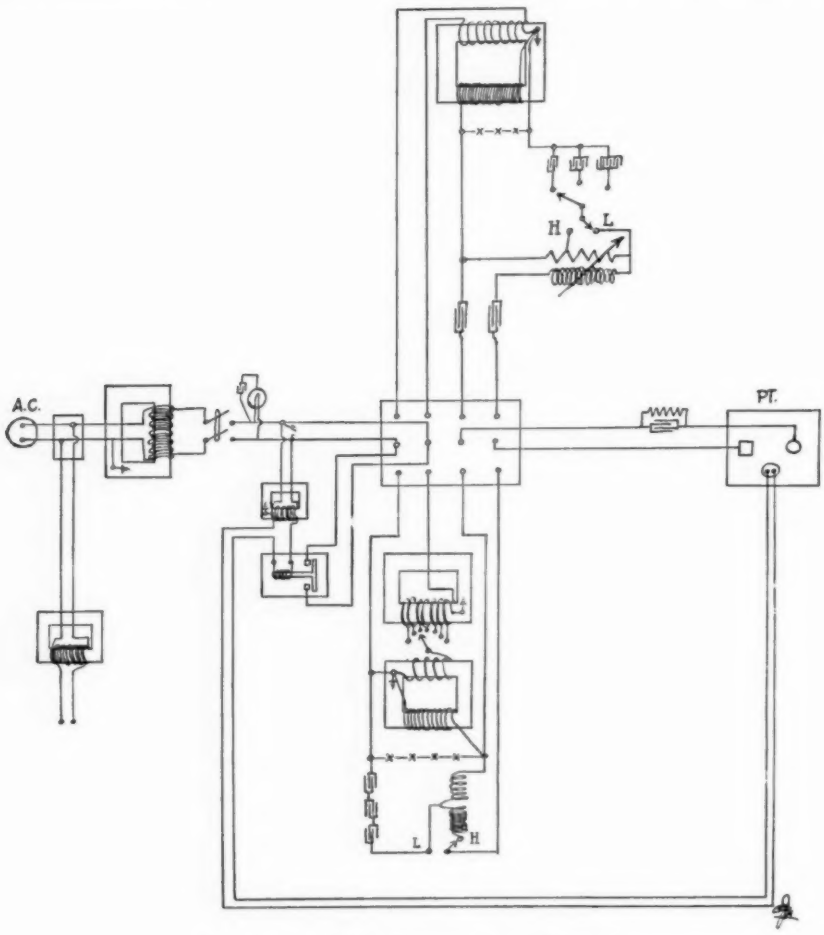


FIG. 5. B. Wiring diagram of machine D.

causes the intense local destruction analogous to a clean surgical incision. Obviously other factors also enter somewhat into the degree of heat developed in actual surgical work: the rate at which the small electrode moves, its size, the depth to which it is embedded, the degree of vascularization of the part, the character (degree of relative resistance) of the tissue. It is in evaluation and control of these latter as well as in the former that the empiric art of electrosurgery lies.

EXPERIMENTAL

Undamped oscillations have been considered as necessary to elicit cutting effects.

A. Experimental Unit (Fig. 2). *Construction:* In order to obtain as smooth (faradic-free) an experimental current as

Fig 6. A. Commercial gap machine E. Spark gaps encased on right; variocoupler and reactance in foreground.

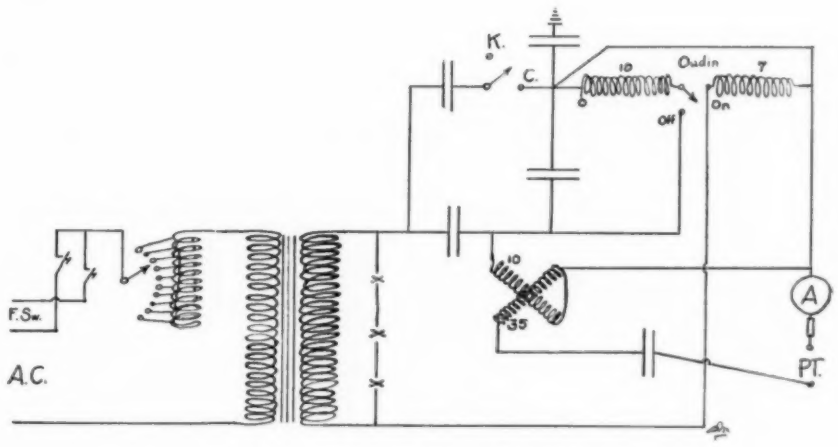


Fig. 6. B. Wiring diagram of machine E.

As a matter of fact an electrode delivery of 6 to 30 watts in undamped (triode) oscillations produces excellent cutting, while 20 to 75 are usually necessary with damped (spark gap) oscillations; the reasons for this have been considered elsewhere.[15] Since the efficiency of most electrosurgical machines of whatever type averages from 10 per cent to 30 per cent, less ruggedness and greater facility of construction has until recently been more possible with the former type of cutting apparatus. For experimental work, in addition, a proper triode set-up allows maximum flexibility in sharp control both of frequency and of amplitude of oscillation.

theoretically possible, filtered direct current was used to apply voltage to the tank circuit carrying radio frequency oscillations; a Hartley type radio-frequency circuit was chosen because of its reliability of performance. Interchangeable radio-frequency coils of large flat-wound copper wire were balanced against an ascending series of variable and fixed condensers to obtain oscillations ranging from 250,000 to 4,600,000; amplitude was flexibly controlled by a series sliding resistance and a 7-point reactance inserted in the power primary circuit, sufficiently strong at maximum to obliterate entirely any flow of current into the tank circuit.

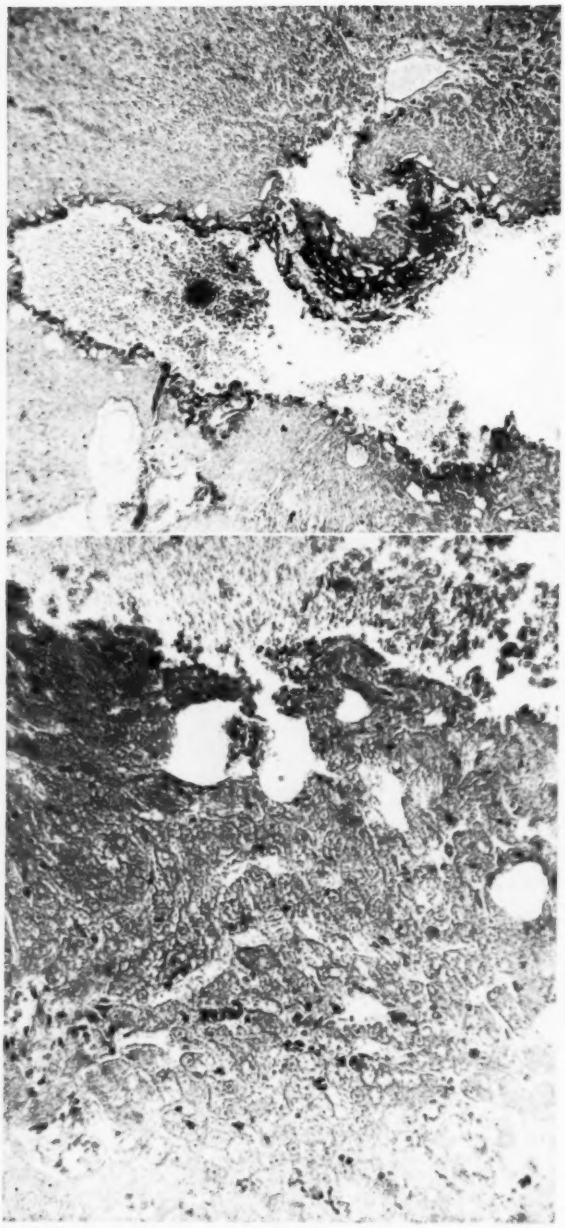


FIG. 7. Photomicrograph of incision in cat liver, made with 220 v. current at 60 cycles per second; electrode 0.013″ diameter, 110 watts. There is 80μ of coagulation necrosis, with ground-glass cytoplasm and pyknotic nuclei; sparse carbonization of epithelium at surface of lip of cut for 3–6μ, and none in depths; there is also 15–20μ of coagulated amorphous serum under epithelium at surface for 150μ to each side. Blood in capillaries in coagulated area stains like hematin; some rare hemosiderin granules and clumps in lumen of incision; erythrocytes normal beyond 80μ. Some interstitial (30–50μ) steam vacuolization in coagulated area, especially at tip of needle. Cells appear normal beyond coagulated zone. H. & E., × 30 and 150.

FIG. 8. Photomicrograph of incision in cat liver, made with 240 v. direct current, electrode negative and diameter 0.013″, about 60 watts. A 3–5μ zone of carbonization, 30μ of coarsely reticulated nucleusless non-staining coagulum; 65μ classic coagulation necrosis, and unaltered cells beyond this; steam vacuolization minor. Cat used in this and Figure 7, was fat and had long been in laboratory; concerning evident non-specific hydropic changes in liver cells, see Ref. 10, p. 131. H. & E., × 30 and 150.

Sixty-cycle current at 110 v. was fed to the primaries of three transformers: (1) Acme 670 supplying 2.5 v. and 5 amp. to each of the 4 mercury vapor radiotron rectifier tubes, (2) G. E. UP 1016 supplying 11 v. and 15 amp. to the filament of the power oscillator tube, (3) and Acme 5181 drawing 10 amp. and supplying ultimately 2200–3000 v. to the oscillator tube plate. The current to the last transformer was passed through a porcelain core sliding resistance in series with a specially wound 7-point reactance (choke coil), these affording control of amplitude. Four UX 866 radiotrons were used to rectify the 2200 v. alternating current from the power secondary, and the resultant unidirectional current smoothed in a filter unit composed of Acme

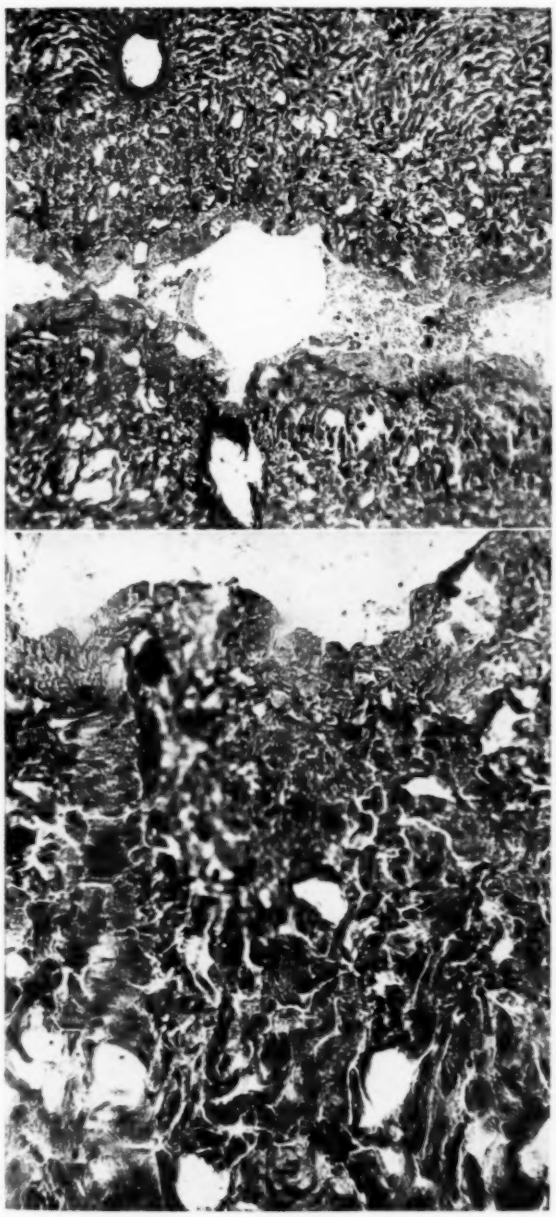


FIG. 9. Photomicrograph of incision in cat liver, made with 0.013" electrode at 4,600,000 oscillations per second and utilizing 45 watts (Table 1, line 18; and Table 6, line A, 9). Total zone of alteration about 250 microns. H. & E., × 30 and 150.

FIG. 10. Photomicrograph of incision in cat liver, made with 0.013" electrode at 1,060,000 oscillations per second and utilizing 30 watts (Table VIII, line A, 5 and Table 1, line 13). Total zone of alteration about 200 microns. H. & E., × 30 and 150.

680 6-henry choke coil and a 674 30-henry choke, with two intercalated Tobe 3320 2-microfarad transformer condensers. The radio-frequency honeycomb choke coil between plate and filter, and, through the grid leak, by a similar coil interposed before the grounded

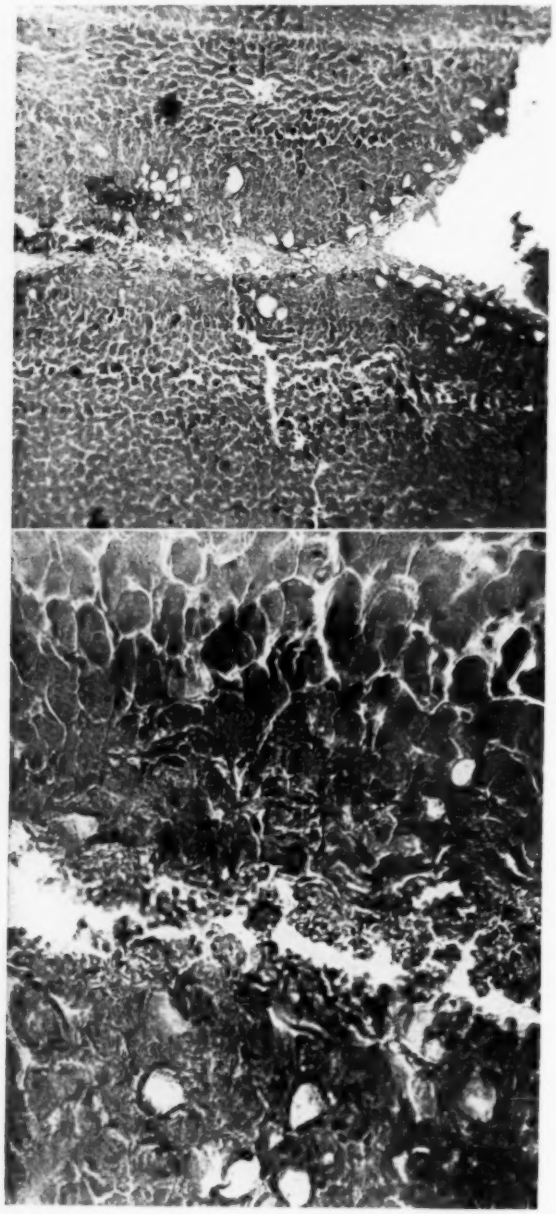


Fig. 11. Photomicrograph of incision in cat liver, made with 0.013" electrode at 3,000,000 oscillations per second and utilizing 100 watts (Table II, line 14 and Table VIII, line B, 1). Total zone of alteration about 60 microns. H. & E., × 30 and 150.

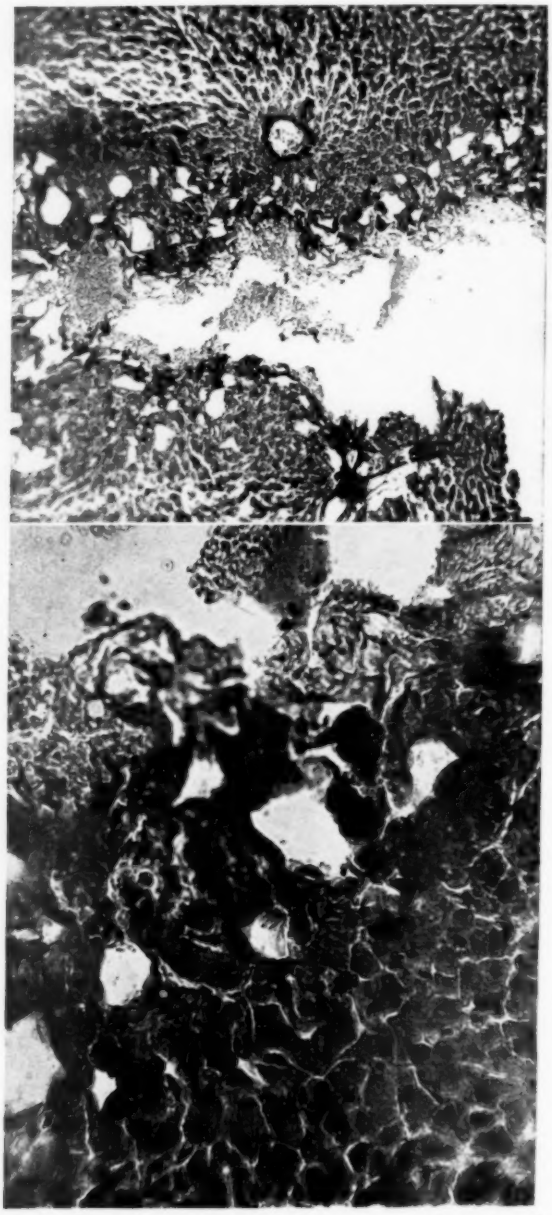


Fig. 12. Photomicrograph of incision in cat liver, made with 0.013" electrode at 3,000,000 oscillations per second and about 70 watts (Table IV, line 2 and Table VIII, line D, 6). Total zone of alteration about 300 microns. H. & E., × 30 and 150.

direct current was then fed to the plate of a 250 watt G. E. UV 204-A, type 251, triode power tube, incorporated in the Hartley circuit; escape of high-frequency oscillations through supply lines was blocked by a 150-turn variable resistance; grounding was accomplished readily through the indifferent wire of the supply lines. The alternating current voltage of the filament was smoothly held constant during operation by grounding the

midpoint of the secondary and each side of the filament, the latter through small 0.0005 by-pass condensers blocking escape electrode. This conduction delivery was thus adequately safeguarded and avoided the clinically prohibitory tuning of another inductively

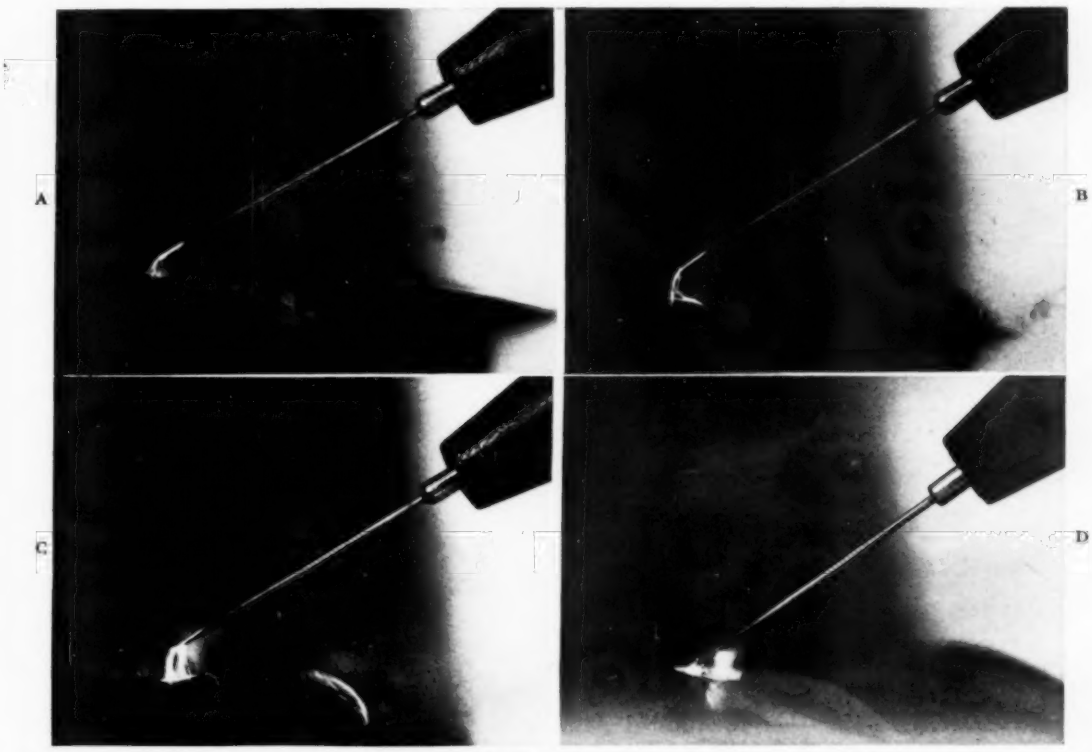


Fig. 13. Instantaneous photographs ($\frac{1}{200}$ second) of discharges produced by coagulating type currents. A, B, and C are from commercial machine D, low voltage medium dehydration, high voltage medium dehydration, and low voltage heavy dehydration. D is from commercial machine B, low voltage.

of the low-frequencies necessary for filament incandescence. The grid connection of the interchangeable radio-frequency tuning coils was fixed; the ground and plate leads were of flexible heavy copper tape terminating in broad clips for selective attachment to the coil; the coils, 5 inches in diameter, were either of copper tubing or of flat-wound heavy copper strip, 15, 30, and 60 turns. The 4 tuning condensers were 2 National TMU 500 variables of 0.5 microfarad capacity and 2 R.C.A.'s (3395 and 1082) of 1 and 2 microfarad capacity respectively, so arranged that they could be successively keyed into the tuning circuit. The patient was protected from low-frequency power currents and from possible flash-over surges in the oscillator by two 0.004 Dubilier condensers interposed between plate and coil, and grid leak and coil. Additional safety was insured, in case of stress breakdown of either of these latter, by a third Dubilier inserted in the cable to the active coupled circuit, with its rare but troublesome fading in emergencies.

Mensuration: Filament voltages, and power table output in amperes and volts, were measured with customary meters. Power output from the radio-frequency table was measured both at the table terminals and again within a few inches of the electrode tips; in the appended tables only the latter values are given;* for measurements here Weston Electric radio-frequency ammeters ranging from 100 ma. to 20 amp. were used; and Rawson electrostatic voltmeters ranging from 100 to 2500

* What goes into a machine, what it delivers at its terminals, and what is delivered at the electrode tips, are entirely distinct things, particularly in high frequency apparatus. It is with the third one of these that the surgeon is concerned, and into which he should, and this article does, inquire.

v., higher voltages being measured on a special ball-electrode micrometer spark gap. The complete accuracy of the foregoing measuring devices, at upper ranges of frequencies investigated, may be doubted. Wave length and frequency were determined with a General Radio precision wavemeter, Type 224, having range from 70 to 24,000 meters; frequency was determined both at coils of machines and in final reaches of the cable supplying the active electrode. Electrode diameters were measured with a screw micrometer. Measurements of resistance were made on a direct current potentiometer. Time for incisions was usually estimated with a stop watch.

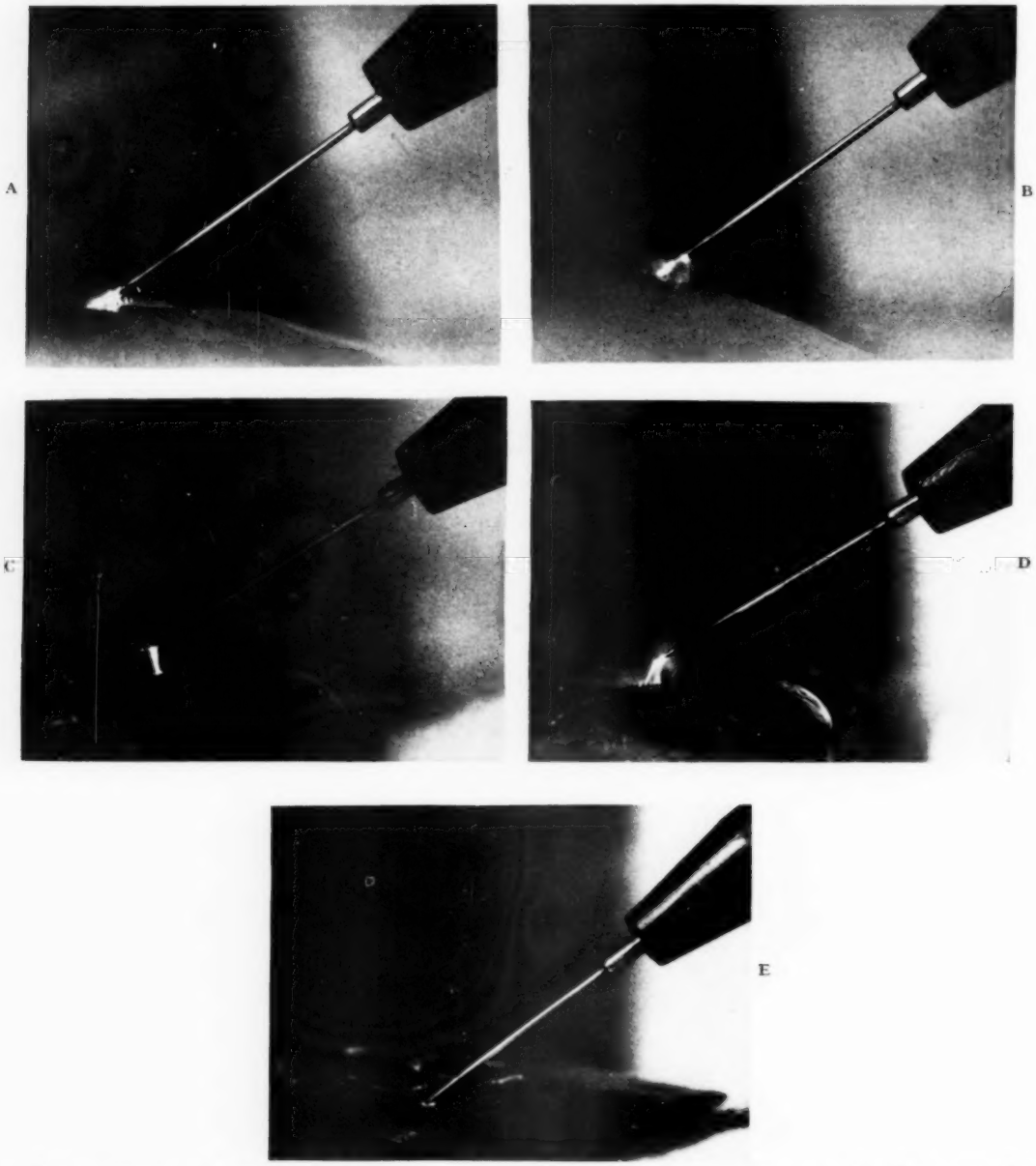


FIG. 14. Instantaneous photographs of discharges produced by cutting currents. A and B from experimental unit, C and D from commercial machine D, and E from commercial machine E.

Fresh or living liver (4700–9000 ohms) was used uniformly for making incisions, because of the ease with which zones of alteration may be estimated in gross

These estimations are relative, but have been checked histologically personally many times in the past as well as frequently during the progress of this present work; only in gaping and everted incisions made with high voltage, producing flame burns, is there persistent tendency to overestimate somewhat in gross the extent of microscopic alteration. Tissues were uniformly fixed immediately in Zenker's solution, embedded in paraffin, stained with eosin-methylene blue or with hematoxylin and eosin. Histologic zones of penetration were measured with a calibrated ocular micrometer.

Results: The results are tabulated as follows (Table 1):

delivered to the active electrode; below this voltage cutting did not appear. The rate at which the incision could be made was a rough function of the delivered wattage; and the extent of lateral coagulation tended to parallel the delivered amperage, with an optimum mean of about 100 ma. Frequency had no appreciable bearing upon quality, rate or character of incision. Though more power apparently was impounded in the tank circuit here at peak in higher frequencies, only amounts of power roughly homologous to those at lower frequency were deliverable (or desirable) at the electrodes.

When peak voltage fell below critical 200 only desiccation effects were possible.

Table 1

	Input (Watts)	Output					Incision 3 Mm. Deep and 10 Cm. Long		Remarks
		Voltage		(Ma.)		Watts			
		Peak*	Op.*	Peak	Op.	Op.	Time	Lat. Coag. μ	
270,000/sec. 1	101	1,200	450	55	300	135	0.3	700–900	Bad flame burn 2–6 mm.
2	95	1,050	275	50	250	68	0.7	200–400	Bad flame burn 1–2 mm.
3	84	800	275	45	160	44	1.0	200–400	Slight burn
4	41	500	225	30	80	18	3.5	100–300	Good incision
5	31	250	225	15	25	5.6	8.0	100–200	Good; very slow
6	9	50	25	±	±	?.02	....	.....	Spt. desicc.
600,000/sec. 1	89	950	275	160	140	38	1.5	150–250	1–2 mm. flame
2	72	825	250	145	120	30	3.0	100–150	0.5 flame
3	42	650	225	110	80	18	4.5	100–150	All right
4	25	375	200	40	30	6	6.5	100–150	Good; slow
5	10	175	0	15	0	?o	....	.....	Spt. desicc.
1,060,000/sec. 1	59	950	225	350	100	22.5?	3.5	200–500	0.5 burn
2	54	825	250	300	120	30	3.8	200–400	All right
3	48	650	225	260	110	24.7	4.0	150–300	All right
4	27	425	225	170	100	22.5	6.5	150–300	All right
5	18	250	225	100	55	12.4	17.0	50–100	All right
6	7	?25	25	20	20	0.5	....	.....	Vspt. desicc.
4,600,000/sec. 1	103	800	150	900	300	45	2.5	100–200	Brilliant arc under tissue
2	74	550	125	650	300	37	3.0	100–200	High whine
3	33	440	150	500	250	37	5.5	50–150	High whine
4	14	300	200	310	200	40	12.0	50–100	
5	4.8	50	0	230	0	?o	....	.....	Vspt. desicc.

* "Peak" readings, throughout these tables, are measurements of energy just before the active electrode is placed in contact with the tissue; "operative" readings are those obtained during the actual cutting or coagulation. Both were obtained by instruments within a few inches of the active electrode tip.

Comment: From Table 1 will be seen that good cutting occurred when 200–225 v. were

Optimum wattage for a good incision had a mean about 18–25, and when peak

voltage rose above 750 the operating voltage tended to rise above 225 volts (optimum) with resultant production of undesirable flame burns on the surface.

B. Commercial Triode Machine (Fig. 3). This recent compact machine, operating at a fixed frequency of 3,000,000, omits the unnecessary direct current for plate voltage, and applies stepped-up alternating current directly to the plates of two triode tubes acting as self-rectifiers and each using one-half of the low-frequency cycle. Amplitude of oscillation is primarily controlled by electron depletion within the tubes, through a 5-point tube filament rheostat; grades of cutting and of coagulation are further obtained by tapping the radio-frequency coil at varying distances from its center ground, each lead passing through a small protection condenser.

Construction: Sixty-cycle alternating current at 110 v. is fed to a primary coil of a transformer exciting two secondary coils, one, a step-down coil, supplies the 10 v. for the filaments through a 5-point rheostat, and the other, a step-up winding, supplies the thousand volts to be impressed on the plates of two G.E. UV 203-A tubes. Loss of radio-frequency oscillations into supply lines is prevented by radio-frequency choke coils of about 130 turns of cotton-covered wire (20 turns per centimeter) on a bakelite core 3.5 cm. diameter. Grid leaks are taken care of by 5000 Vitrohm resistances bridged across 0.0005 condensers. Oscillation frequency is determined by the grid tap (at 9 turns) on the r.f. coil and by the small 0.002 mfd. Dubilier mica condensers (Type 580). The r.f. coil itself is 49 turns of 1 mm. bus wire on a grooved 9 cm. hollow bakelite core, with 3 mm. space between turns, the coil being tapped at center for ground (body), at 5, 7, and 9 turns for slow, medium, and fast cutting, and at 4 and 25 turns for coagulation and desiccation; each tap is led through a protective 0.0005 mfd. condenser.

Results: The results are shown in Table II.

Comment: Here again the rate of incision paralleled the delivered wattage; the optimum however was between 40–80 watts. When the delivered voltage rose above 250, surface flaming occurred, marring the incision. The milliamperage delivered for satisfactory incisions ranged from 190–300.

During coagulation, peak and operating voltage, amperage, and wattage were identic. The voltage remained low, and when it reached critical 200, cutting effects appeared. With the appearance of cutting at critical voltage, peak and operating identic relation no longer held, as power was absorbed in persistent arc ionization.[15]

C. Commercial Triode and Gap Machine (Fig. 4). This excellent pioneer of generally utilizable clinical machines met squarely the necessities of its time by incorporating a flexible triode cutting outfit, and a versatile spark gap coagulating outfit in one cabinet, both independently feeding a single pair of electrodes. It however has a multiplicity of necessary controls, and requires what is generally considered bothersome tuning despite the fact that it operates at a substantially fixed frequency. Being inductively coupled to the patient, its delivery circuit sometimes fades annoyingly, although this clinical unreliability is exceedingly rare.

Construction: Sixty-cycle alternating current at 110 v. is led to a selector switch diverting it to either cutting or coagulating units. On the cutting side, it passes through a 5-point reactance (choke coil) feeding the high tension primary of a transformer whose secondary winding charges condensers and furnishes voltage to the triode plates. The low-tension current also lights the triode (two 50 watt 211-D Westinghouse) filaments, whose voltage is controlled to steady maximum efficiency through a rheostat thrown across the line. The charging of the condensers momentarily activates the primary of the r.f. transformer and inductively excites controlling oscillations in the neighboring variocoupler and its parallel condenser, these oscillations being transmitted to the grid. Frequency at about 300,000 is largely determined by the fixed tuning condenser across the plate end of the r.f. primary, while amplitude is controlled through the grid, though this circuit also secondarily affects frequency; this gives two controls of

amplitude: reactance and grid. The secondary of the r.f. transformer, together with conducting cables and patient, form a third circuit, and this is brought into resonance with the tank circuit by the variocoupler, the neon glower lamp being used to find maximum efficiency of power transmission.

When the selector switch is thrown to the coagulating unit, it again passes through a controlling reactance before reaching the high tension transformer; beyond this are four air-cooled micrometer spark gaps and two condensers, in the usual arrangement for production of damped oscillations;[18] the patient is further protected against electrical defects by intercalation of another condenser in one of the cables to the terminals. The excitation of the hot end of a Oudin coil (for desiccation) is controlled by a separate switch on the panel face.

Table II

		Output					Incision 3 Mm. Deep and 10 Cm. Long		Remarks
		Volts		Ma.		Watts	Time	Lat. Coag. μ	
		Peak	Op.	Peak	Op.	Op.			
	Rheo.								
Slow cutting	1*	225	220	160	190	41.8	3.5	100–200	
	2	225	220	190	235	51.7	2.5	100–200	
	3	275	225	225	250	56.2	2.0	100–200	Sl. brown sear
	4	275	225	225	300	67.5	1.5	100–200	
	5	300	225	275	315	70.8	1.2	150–250	Initial flame
Med. cutting	1	225	215?	160	190	40.8	2.5	150–200	Clean beautiful current
	2	250	220	200	250	55	2.0	150–200	
	3	300	250	250	300	75	1.5	175–250	
	4	325	250	290	350	87.5	1.2	175–200	Initial slight burn
	5	380	250	310	400	100	1.0	175–200	Initial slight burn
Fast cutting	1	300	225	225	275	61	2.0	150–200	
	2	350	225	275	310	69.7	1.5	150–200	
	3	400	250	300	350	87.5	1.2	200–300	Flame burn each end
	4	440	250	300	400	100	1.0	200–300	Flame burn each end 30–80μ
	5	500	275	400	490	134.7	0.7	200–400	Flame burn each end 30–80μ
Coag.	1	100	100	±	±	0.1	0	0	0.5 mm. in 1 sec.†
	2	150	150	50	50	7.5	0	0	1 mm. in 2 sec.
	3	175	175	100	100	17.5	0	0	
	4	200	200	150	125	25	4.5	150–200	1 mm. in 1 sec.
	5	225	200	200	150	30	4.5	200–250	Burn hole about needle; 1 mm. coagulation beyond
Desicc.	1	650	50	350	0	0.05?	3.5	200–500	Gapes
	2	775	150	450	0	0.05?	3.5	200–400	Gapes
	3	825	150	500	75	12	4.5	300–500	Gapes
	4	800	200	500	75	15	4.5	500–600	Gapes
	5	900	200	550	75	15	2.5	500–600	Gapes

* Filament voltages, rheostat stop No. 1, 7.5 v.; No. 2, 8.0; No. 3, 8.5; No. 4, 9.5; No. 5, 10.2 volts.

† Coagulation was uniformly tested throughout the investigation by inserting needle electrode 1 cm. into tissue, and noting time to produce maximum effect.

Results: The results are given in Table III.

Comment: Triode unit: Adequate cutting effects were obtained with a delivery of 15–25 watts. When the delivered voltage rose above 225, flame burns about the surface of the incision detracted from

TABLE III

Frequency	Output					Incision 3 Mm. Deep and 10 Cm. Long		Remarks
	Volts		Ma.		Watts	Time	Coag. μ	
	Peak	Op.	Peak	Op.	Op.			
a. Triode cutting panel:								
300,000 (Variom. 7)								
1	150	150	0	40	6	6″	240–300	Feeble cut
2	200	200	0	100	20	3½	200–300	Fair cut
3	275	225	0	100	22.5	2½	400–500	Good cut
4	350	225	0	160	36	2	100–200	Slight flame start
5	440	300	+	250	75	1.5	300–700?	More; side of incis. seared tan
312,000 (var. 3)								
1	150	150	0	70	10.5	5	150–200	
2	225	175	0	100	17.5	3½	200–400	Superb cutting
3	300	225	0	110	24.7	2½	300–400	
4	375	250	0	150	37.5	2	200–300	
5	440	300	+	230	69	1.5	300–400	Slight flame burn
292,000 (var. 0)								
1	0	50	0	20	1.0	9	100–200	Very poor cut
2	175	150	0	80	12.0	4.5	200–400	
3	250	225	0	110	24.7	3.0	200–300	
4	300	225	0	140	27.5	2.0	200–300	
5	400	300	+	220	66.0	1.5	200–400	Slight flame burn

b. Triode coagulating panel:

									Coagulation:	
272,000 (var.-3)	1	...	...	..	..	....	Vspt.	Desicc.	1.5 mm. in 4 min.	
	2	...	...	..	..	....	Vspt.	.....	2.0	4
220,000	3	...	...	..	..	....	Vspt.	.....	2.0	2½
(var.-7)	4	...	...	..	..	....	Vspt.	.....	2.0	1½
	5	200	175	0	45	10.5	6½	400–600	2.0	½

c. Spark gap panel: Frequency: A broad band extending from 337,000 to 800,000, with its major output between 525,000–571,000; alteration of gap aperture does not appreciably affect distribution of frequency.

	Coagulation								Fulguration								
	Voltage		Ma.		Watts	T.	Change Diam. mm.	Crater Diam.	Voltage		Ma.		Watts	J*	D*	C*	D*
	Peak	Op.	Peak	Op.	Op.				Peak	Op.	Peak	Op.	Op.				
1	?0	±	0	80	0.08	60″	8	0.1	0	75	0	20	1.5	1	Spray, without effect		
3	175	150	0	250	37.5	30	15	1.0	75	100	±	70	7.0	4	5	0.5	2.5
5	250	200	30	380?	76?	15	15	3–4	200	225	20	70	15.7	5.0	5	1	2.5
7	225	200	50	340	68	15	15	3–4	225	225	30	90	20.3	5	5	2	3
9	250	225	50	300	67.5	8	15	3–4	250	225	50	130	29.3	5	6.5	3	3.5
10	...	...	..	....	.....	..	..	...	300	300	70	150	45	5	6.5	3	3.5

Table III (*Continued*)

d. Oudin current:
Frequency 1,363,000–1,430,000

	Voltage		Ma.		Watts Op.	J	D	C	P
	Peak	Op.	Peak	Op.					
1	400	400	±	±	?	5	Pract. nothing		
3	600	600	±	±	?	7	3	0	300
6	925	850	±	±	?	7	4	0	500
9	1000	850	±	±	?	7	4	0	500

* J: distance (mm.) intervening between electrode tip and tissue at time spark first jumped. D: diameter of superficial change produced in tissue (mm.). C: width of crater blasted in central part of coagulated area. P: depth of penetration of coagulation into tissue.

surgical desirability. Frequency low, and here, as in first section of Table 1, a smaller recorded wattage produced more lateral coagulation than greater amounts at higher (Table 11) frequency.

Gap unit: In coagulation a maximal radial penetration of 7.5 mm. could be attained with 35 watts; increased amperage only lowered the time for this penetration to occur; again, peak voltage above 250 produced charring. In fulguration a maximal spark of 5 mm. was obtained, at 225 v.; above this, only amperage showed consistent increase, and with it some minor increase in the zone of coagulation, at the expense of carbonization of the central zone. In desiccation (Oudin coil), the spark was 7 mm., dispersion and penetration far less; the amperage was immeasurably low and the voltage ranged from 500 to 1000.

D. Commercial Spark Gap Machine (Fig. 5). This steadily improved sturdy apparatus has been the outgrowth of one of the early primitive cutting machines and its reliable performance has contributed materially to the strong entrenchment of electrosurgery in this country.

Construction: Line supply of alternating current, 60-cycles, 110 v. and 10 amp. is introduced on the left of the diagram. A tap leading to an insulating transformer supplies current for the operator's headlight, and to the insulating transformer for the entire machine. This transformer, as well as all others beyond it is grounded through the supply wiring in order to keep the machine's oscillating potential symmetrically above and below zero potential. A main line switch, pilot lamp, auxiliary contact switch are interposed before the giant selector switch is reached.

The median four terminals of the selector furnish a low-frequency inlet, and an egress to the patient for the high-frequency current produced by either of the units depicted above and below it; it is arranged to afford contact with either marginal set of four terminals, throwing into circuit the upper (cutting) unit, or the lower (coagulating) unit, actual egress of the current into either, however, being controlled at a distance by the operator through the magnetic relay (foot or hand) switch.

In the cutting unit, the voltage is stepped up by a special transformer, and used to charge selectively one of three condensers of fixed capacity; the larger the condenser, the greater the initial amplitude of the damped wave, and the resultant dehydrating penetration in the tissue. Flexibility is further enhanced by introduction of a variometer with a selective low or high voltage winding on the outer (stator) drum, the inner drum being arranged to revolve at will to cut with increasing effectiveness the electromagnetic lines of force set up by the stator windings. Additional condensers are interposed on each line beyond the variometer in order to protect the patient from low-frequency jolt if a fault should develop in the dielectrics of the condensers of the generating circuit.

In the coagulating unit, current led into a reactance is tapped off at any one of 7-points and fed to a step-up transformer, beyond which are a coarser spark gap and three condensers in series, the latter arrangement being chosen for safety to reduce the pressure

TABLE IV

The fundamental frequency of the cutting unit is 3,000,000 though as the variometer is increased the frequency falls to 2,500,000; with light dehydration when varimeter is at maximum, at both low and high voltage, a considerable number of bands appear from 1,600,000 to 4,000,000; if gaps are widened at any time the frequency band is maximally broadened by 50,000–100,000 oscillations. The coagulating unit produces several close set frequencies; the main band (probably 60 per cent) is at 1,111,000, secondary bands are at 1,000,000 and 1,350,000; and a tertiary band at 1,200,000.

Cutting unit:

	Low Voltage							High Voltage						
	Volts		Ma.		Watts	Incision 3 Mm. Deep and 10 Cm. Long		Volts		Ma.		Watts	Incision 3 Mm. Deep and 10 Cm. Long†	
	Peak	Op.	Peak	Op.	Op.	T.	Coag. μ	Peak	Op.	Peak	Op.	Op.	T.	Coag. μ
Var. Light 0	0	0	0	0	0	...	.....	0	0	0	0	0		
50	600	225	310	250	56	2	50– 100	1025	250	425	275	68.7	2	500–1000
100	875	250	350	275	68.7	0.5	200– 400	1025	250	400	400	100	1	200–1000
Med. 0	0	0	0	0	0	...	.....	0	0	0	0	0		
50	450	225	200	350	78.7	2.5	100– 200	800	200	400	250	50	0.5	500– 800
100	600	250	250	300	75	0.5	500– 700	800	225	350	450	101.2	0.5	1000–1500 c burn
Heavy 0	0	0	00	0	.....	...	.....	0	0	0	0	0		
50	400	205	160	240	48	4.0	400– 600	400	200	100	75	15	0.5	500– 700 poor
100	700	250	200	600	150	0.5	700–1000	775	220	300	400	88	0.5	1000–2000 c burn

*Fulguration:**

	Low Voltage									High Voltage								
	Volts		Ma.		Watts	J	D	C	P	Volts		Ma.		Watts	J	D	C	P
	Peak	Op.	Peak	Op.	Op.					Peak	Op.	Peak	Op.	Op.				
1	0	0	50	50	?0.05	0.5	without effect			0	0	0	0	....	2	2	0	0
2	0	0	50	50	.....	0.5	0.5	0	0	0	0	0	0	....	2	2.5	0	0.2
3	0	0	75	50	?0.05	1.0	0.5	0	0.1	50	0	0	00	....	2	3	0	1
4	25	25	300	100	2.5	1.5	1.5	0	...	100	100	50	50	5	2	4	0.5	1.5
5	100	100	450	100	10	1.5	1.5	0.5	...	150	140	100	100	14	2.5	5	0.5	1.5
6	200	200	550	200	40	1.5	3.0	1.0	...	250	250	200	200	50	3.5	6	1.0	1.5
7	250	250	650	300	75	1.5	5.	2	...	300	275	275	275	75.6	4	7	2.5	1.5

Coagulation:

	Low voltage				High voltage			
	T	D	Coag.	Remarks	T	D	Coag.	Remarks
1	..	0	0	.....	....	0	0	
2	30″	1	1	.....	30″	4–5	3	
3	30	3–4	2.3	Clings	12″	4–5	3	Clings
4	14	4	3	Clings	5	4	3	Clings
5	9	4	3	Clings	2	4	3	Clings
6	5	4	3	Clings	1.5	5	3	Crater
7	4	5	3	Black crater	1	5–6	3	Crater

* Investigated with needle electrode of 0.026 inch diameter; Tables I, II, III, and V with 0.014 inch electrode.
† In making deeper cuts, voltage usually falls slightly and amperage rises, depending on the depth of cut.

strain occurring across a single condenser. These lead to a coarse self-induction resonator coil, with both high and low voltage taps. The lead lines to the patient are equipped with a filter device similar to a grid leak, whereby adventitious low-frequency surges and harmonics are baffled by a proper sized condenser and their charges allowed to dissipate harmlessly slowly through the high resistance bridge.

Results: Table IV gives the results.

Comment: Cutting unit: Surgically satisfactory incisions were accomplished with 30–75 watts. Increasing the amperage in general enhanced lateral coagulation. In general increased "dehydration" meant increased wattage, largely through increased utilization of amperage. Best routine cutting was found at "high voltage, light dehydration, variometer 40." When delivered voltage rose above 225, undesirable flame burns appeared. Higher ranges of variometer dial readings could accomplish substantial fulguration, not distinguishable in surgical effect from intemperately vigorous Oudin phenomena.

Coagulating unit: In coagulating, radial penetration increased with wattage to a maximum of 3–4 mm., for the spark gap set in ordinary utilizable width; as wattage increased, the time necessary to produce maximal coagulation symmetrically diminished. In fulguration, a maximal spark of 4 mm. was obtained, but most satisfactory operative results were obtained with a 2 mm. spark at 100 v. (2 mm. penetration, with minimal carbonized eschar).

E. Commercial Spark Gap Machine (Fig. 6). This recently devised truly portable unit utilizes the same spark gap for cutting and for coagulation, the variation in condenser size being such that satisfactory coagulation can usually be obtained without resetting, merely by throwing the tumbler switch from knife to coagulation; the "coagulating" current also cuts, but with greater lateral coagulation. A reactance affords main current control, though a rather weak variometer allows some final graduation as well.

Construction: Sixty-cycle alternating current at 110 v., after passing through a 10-point reactance is stepped up by a high tension transformer and used, when cutting, to charge a single condenser creating damped oscillations by discharging through three micrometer spark gaps; when coagulation is used, however, two additional condensers are entered in series-parallel, lowering voltage and increasing amperage. A Oudin coil is activated when desired by a separate switch. A protective condenser is interposed between the variometer and the patient.

Results: The results are shown in Table V.

Comment: Again, with a gap machine, cutting appeared at about 30 watts, and was satisfactory to 75 watts; above 225 volts, flame burns appeared at the initial and parting contacts. The time varied inversely with the wattage, but lateral coagulation was not appreciably affected by amperage increase in the middle ranges.

With the switch thrown to "coagulation," cutting appeared at between 20 and 48 watts, with somewhat greater lateral coagulation than "knife," but otherwise the statements given above hold for this modality as well. In fulguration, the spark was at a fraction of a millimeter, with 0.5—1.0 mm. radial coagulation. In coagulation a 1.5 mm. radial effect was produced in 2 seconds at maximum.

In Oudin desiccation, the spark jumped maximally 4.5 mm. but could be drawn out to 6 mm. before quenched.

Low-Frequency Cutting

Since ordinary low-frequency electric currents produce burns, there is no reason why they should not also be made to counterfeit electrosurgical incisions if applied through surgical electrodes. Such currents kill, as elucidated in the introduction, but they cut identically, clinically and histologically, as do high-frequency currents.

Alternating current results are given in Table VI.

TABLE V

Major frequency when cutting (80 per cent) is 545,000, though a fainter broad band from 460,000 to 545,000 is present, and feeble oscillations appear both at 300,000 and 1,500,000. When coagulating, major frequency (about 65 per cent) is 460,000–480,000, with some at 420,000–550,000, and with the same feeble oscillations as on cutting. Oudin frequency is sharp at 706,000 per sec.

Knife:

	Voltage		Ma.		Watts Op.	Incision 3 Mm. Deep and 10 Cm. Long		Remarks
	Peak	Op.	Peak	Op.		Time	Lat. Coag. μ	
Reac. 1*	0	0	10	10	?	0		
2	100	100+	25	40	4.	Streaks, but no depth		
3	100	150	55	65	9.7	Streaks, but no depth		
4	100	150	70	85	12.8	Streaks, but no depth		
5	300	200+	110	180	36	3.5	100–300	Dry tannish brown seal
6	325	200+	130	220	44	2.2	100–300	Dry tannish brown seal
7	350	225	140	300	75	2.0	100–300	Dry tannish brown seal
8	350	225	155	300	75	1.5	100–300	Dry tannish brown seal
9			(Blows 10 amp. fuse)			1.5	200–350	Dry tannish brown seal
10			(Blows 10 amp. fuse)			1.0	200–400	

Coagulation:

	Voltage		Ma.		Watts Op.	Time	Incision Lat. Coag. μ	Remarks	Coagulation Effects			
	Peak	Op.	Peak	Op.					T.	D.	Coag.	Remarks
Reac. 1*	0	0	0	0	.....	0	0	.....	Spt.	desic.		
2	50	±	±	55	0.05	0	0	Sticks	...	0.5		
3	150	±	35	70	0.07	0	0	Sticks	...	0.8		
4	200	150	60	135	20.2	0	0	Streak; no cut	...	1.0		
5	325	225	75	215	48.4	3.5	200–400	Cut	3″	1.5	1.5	Cling
6	400	250	100	275	68.7	2.0	200–350	Vigorous cut				
7	425	250±	110	325	81.2	2.0	150–300	Vigorous cut				
8	450	250±	110	400	100.	1.5	200–300	Vigorous cut				
9	...	.....	...	...	.....	1.0	200–300					
10	...	.....	...	...	.....	0.7	200–400	.....	2″	2.5	2.5	Nocling;char

Oudin:

	Volts		Ma.		Spark		Remarks
	Peak	Op.	Peak	Op.	Initial	Quench	
1	0	25	0	0	0	3	Puckers only
2	200	0	0	40	0	4	Puckers only
3	400	100	65	65	½	4½	Puckers only
4	550	400	100	100	3.5	3.5	Crater and 3 mm. zone
5	775	450	140	120	3.5	3.5	
6	825	475	160	155	4.5	5.0	1 mm. deep, 4.5 diam.
7	925	600	170	160	3.0	6.0	Carbonizes
8	975	750	180	175	4.0	5.0	Carbonizes, with a flame burn

* Variometer constantly at maximum.

Table VI

60 cycles: (electrode 0.023" diameter)

Volts	Amp.	Watts	Remarks
110	.....	.....	Slight sputtering, no cutting.
140	0.075	10.5	Very poor cutting; 7 sec. to make 10 cm. cut 3 mm. deep.
140	0.23	32.2	Fair cutting; 3 sec. for a cut 10 cm. long and 3 mm. deep, and 11 sec. for cut 10 cm. long and 1 cm. deep.
220	0.5	110	Good cutting to any depth, 10 cm. long in 3 sec.; only 100–300μ lateral coagulation.
500	0.5	250	Excellent quick cutting; no flame; only 100–300μ lateral coagulation.

In view of the foregoing, *direct current* was tried, using the large Cruft Laboratory battery in order to eliminate any possibility even of commutator ripple; no other leads or taps were in circuit. The cutting electrode was negative and cool. The results are shown in Table VII.

Table VII

Volts	Amp.	Watts	Remarks
120	....	....	No cutting; very slight coagulation about the needle point.
180	0.30	54	Good cutting, 4 sec. for 10 cm., cut 3 mm. deep.
240	0.24	57.6	Excellent cutting to any depth, 3 sec. 10 cm. long and 3 mm. deep; 4.2 sec. (144 watts) for 10 cm. cut 1 cm. deep; only 200–500μ coagulation lat.

With polarity reversed the needle became red to white hot during cutting, and sparking and searing were more marked; amperage readings were also 25 per cent higher.

Some photomicrographs of these cuts are given in Figures 7 and 8 for comparison with ones of analogous wattage in high-frequency currents. As larger electrodes are used the zone of carbonization widens, hemosiderin appears in the capillaries in the proximal zone of coagulation, steam vacuoles are larger and more frequent, and tissue is more disrupted physiomechanically. Carbonization is not apparent microscopically in incisions with the negative pole electrode.

Comment: Here, with a slightly larger electrode than in experiments detailed before, incisional effects could be produced at 10 watts, but surgically satisfactory cutting was not obtained until about 30 watts were delivered; furthermore, sluggish but adequate incisions could be affected at 140 v.; at 220 v. however effects were consistent and free. It is notable that flame burns did not appear at low frequency even at 550 v.; nor with direct negative current up to 240 v. (though with polarity reversed flaming and sparking spoiled every incision).

HISTOLOGIC FINDINGS

General: Cuts made by any of these electrosurgical machines have shown common general characteristics histologically; different modalities and different machines produce varying depth of zones, or occasionally omit a zone, but a recent electrosurgical incision is readily recognizable as such. These general divisions, illustrated in parenchymatous tissue, commencing at the face of the incision and thence progressing in penetration are:

Carbonization: 1–15μ. Black and brown common granular resolution of all structure; easily wiped away even by the passage of the electrode; frequently wholly absent in surgically excellent incisions. Usually significant of excessive voltage.

*Hyalinization:** 6–50μ. A formless, slightly granular, deep pink-staining, molecular disintegration in which rare distorted nuclear or cystoplasmic outlines may be suggested, but predominantly utterly without structure.

Desiccation: 5–30μ. Corresponds to the mummification necrosis of Clark, Morgan and Asnis[8]; essentially an extraction of fluid from cells. Cytoplasmic and nuclear

* Though this is accurately descriptive, the change indicated by this term has only apparent resemblance to the chronic change called hyaline degeneration.

outlines are intact, but considerably collapsed in varying degree upon themselves; vivid staining; not mere pyknotic change. Throughout this, *and the zone of coagulation*, steam vacuoles, sometimes containing a small amount of precipitated albuminous fluid, are found in varying abundance and size, if the structure of the tissue is such as to allow their formation.

Coagulation: 20–700μ. Classic coagulation necrosis, with intact or rarely pyknotic nuclei and vitreous deeply-staining cytoplasm. Blood cells within capillaries contained in the distal half or two-thirds of the zone are intact and unharmed. Rarely, if electrode movement has been sluggish, the coagulum in the depths of the incision will have shrunk somewhat, freeing occasional individual parenchymal cells into microscopic lakes of plasma intervening between this and the next layer; primary healing is then dubious.

Viable: 5–250μ. A zone containing occasional rounded cells, and a few with deeply-staining cytoplasm; nuclei and chromatin network everywhere however are essentially unaltered, and this zone is viable.

Table VIII

			Carbon	Hyalin	Desic.	Coag.
A. 270,000	1		9–11	6–10	6–10	180–200
	2		6–10	10–12	?0	150
	3		3–5	3–8	?0	100
1,060,000	1		30	20–30	15–45	240
	2		15	25–30	10–60	180–300
	3		3–6	20–25	30–60	120–150
	4		10–15	15	30–45	60–90
	5		0–10	?5	30	50–60
4,600,000	1		6–8	16–20	75–100	150–200
	2		3–6	15–18	30–50	125–150
	3		2–4	15–18	30–45	40–150
	4		2–4	12–15	15–45	60–240
B. Fast	4	Small	0–2	18	10–18	6–12
		Large	0–2	18	6–18	30–90
Slow	4	Small	1–3	3–4	8–10	6–100
		Large	4–8	6–12	4–10	90–120
C. Voltage control	2	6 knife	6–9	3–6	3–6	50–100
		3	3–6	3–6	0–3	3–40
		0	0–3	0–3	0–3	30–100
		3	0–15	0–15	20–40	120–150
		6 coag.	?	+	25–30	180–200
Voltage control	4	6 knife	6	3–6	?–3	70–80
		3	6–9	3–6	0–3	120–150
		0	6–9	10–40	30–40	170–190
		3	6–9	15–20	.....	250
		6 coag.	10–15	12–15	30–40	200–225
D. Low voltage	50	Heavy	15–18	6–30	0–4	150–250
		Med.	3–6	20–30	3–15	160–200
		Low	0–3	15–20	15–30	130–160
High voltage	50	Heavy	15–20	10–20	3–6	300–450
		Med.	10–14	10–15	?	300–350
		Low	20–30	20–30	?	200–350
E. Variom., Max.		10 knife	9–12	20–30	40–60	150
		7	6–9	15–30	10–30	110–120
		5	0–3	?	?	80–90

Normal: Beyond this.

Performance: For purposes of comparison the microscopically determined zones of histologic alteration, in microns, produced by various machines and different dial settings, are tabulated as shown in Table VIII.

Previous personal experimentation, and confirmatory investigation here, have shown that uncomplicated primary healing in well-vascularized parenchymatous tissue may be expected to occur if the total zone of lateral damage on one side of the incision does not exceed 250–300 microns; above this primary healing is dubious; and above 600–700 microns secondary intention or even occasional sterile abscess (which may be wholly absorbed) is almost inevitable. It must be realized that these statements are generalities, and that other factors enter into healing than the initial (and major) incisional damage.

The incisions tabulated in Table VIII and illustrated in Figures 9–12 were 10 cm. long and 3–4 mm. deep, and were made with the electrode moving at maximal speed for the dial settings given, without sluggishness or hesitation.

ELECTRODES

If cutting effects are a function of current density, electrode size should exert appreciable effect. The customary needle point used in electrosurgery has a mean hilt diameter of 0.025–0.028 inch; this point is sturdy and mechanically sound. A steel wire of 0.013–0.015 inch diameter is more flexible; for satisfactory use therefore it cannot be more than 1.5–2.0 cn.. long, but this length active tip can be welded onto a mechanically sturdier base. It was thought that the density effect might be reflected in wattage, but it was found rather to be reflected in time. Example (Table IX).

Frequency 1,060,000		Volts		Ma.		Watts Op.	Time
		Peak	Op.	Peak	Op.		
Tap 2	0.013 inch	650	225	260	110	24.7	4.0
	0.026 inch	650	225	260	110	24.7	5.5
Tap 3	0.013 inch	425	180–200	170	85	15.1	6.0
	1.026 inch	425	175–50	170	85	14.9	9.0

It is claimed by a manufacturer that the use of an alloy of tantalum and tungsten as an electrode avoids completely the cling of carbonized tissue to the needle; this was not investigated.

HEMOSTASIS

An attempt to present experimental protocols here is unwarranted, because of the diversity of modifying factors. The chief utility of endothermy, however, lies in its control of capillary bleeding and in lymphatic sealing. Frequency was found to exert no appreciable effect on this, and, within the range investigated (270,000 to 4,600,000), any wattage that produced incision was also initially hemostatic. However, there was variation in plasma-ooze through the walls, late beady formations of blood in a gaping incision, primary control of venules and even arterioles, and degree of manipulation which an incision would stand without loss of hemostasis. The degree of effective stasis in general seemed more nearly to parallel the combined width of the zone of hyalinization and desiccation than to show a consistent relation to the width of the zone of histologic coagulation. Hemostasis of larger vessels effected by electrocoagulation (contact) or by fulguration was histologically merely an intensification of essential incisional processes, with punctate risk of chances of primary healing, due to carbonization, eschar or relatively extensive coagulation necrosis. Since the breadth of zones of hyalinization, desiccation and coagulation is mainly dependent upon amperage, it follows that devices with a greater reservoir of deliverable amperage (within adequate voltage limitations) have roughly, other factors being equal, greater surgical resource.

ARCS

In Figures 13 and 14 are reproduced a few instantaneous photographs ($\frac{1}{200}$ sec.) of various discharges produced by some of the machines investigated. They are in-

dicative of the probable reasons for the different actions of various types of endothermic current. Figure 13 depicts non-cutting endothermic currents; their broad, brush- and tent-like discharges disperse heating effects irregularly over relatively large areas (*a, c, d*) or else wave frond-like with great rapidity from one microscopic area to another (*b*). Those of cutting currents, however (Fig. 14), are seen to be, for the most part, compact, stubby, slim pillars; the energy released is concentrated sharply in one area; the density of the current is high. The cutting effect is not the result of a new property of wave motion inherent in undamped oscillations; it is not even dependent on oscillations (pp. 435, 437), though high frequency oscillations are necessary for its production in the *living* subject.* At the time cutting effects appear in contact application, a new factor absorbing energy enters (as, e.g. Table 11, *d*) the maintenance of an arc, that is, the persistent ionization of the track of current between electrode tip and the tissue.[15] It is the persistent ionization of this tract that prevents dispersion of the current as brush discharge and causes the intense concentration of heating effect (electric arc) whose results under proper conditions is electrosurgical incision. Figure 14 *c, d*, shows in exaggeration the character of the discharge which produces cutting; Figure 14 *a, b*, is an illustration with excessive wattage; and Figure 14 *e*, shows ordinary conditions with an infinitesimal arc which can be seen from above, in the dark, as the electrode advances.

SUMMARY AND DISCUSSION

Adequate current density is the sole general requirement for cutting by electricity. This involves maintenance of an electric arc between the active electrode and the tissue. *Direct current* and *low-frequency current* can produce true incisional effects as well as can high-frequency oscillations of either damped or undamped form. Using surgical electrodes, with direct or low-frequency current, approximately 150 v. are required, and 35 to 150 watts, for an incision of ordinary surgical depth (3 to 10 mm.); the amperage drawn is roughly proportional to the depth of the incision. The function of high frequency in electrosurgery is to afford the non-lethal passage of the necessary current through the living body; its direct participation in incisional effects is nil. In pioneer work it was easier technically to maintain adequate current density with undamped than damped current, but mysterious effects are resident in neither. With *high-frequency current* approximately 225 v. are required for incisional effects, and 18–25 (undamped oscillations) or 30–75 (damped oscillations) watts; the comparative time required for incisions was a rough function of wattage, and the degree of lateral coagulation tended to parallel the delivered amperage (about 1–2 ma. per micron). The critical voltage for cutting effects with high frequency is about 220, and at about 250 undesirable flame burns at the lips of the incision begin to appear.

Electrosurgical coagulation is effected by contact application at voltages less than 200, the depth of coagulation again being a function of delivered amperage; if voltage is too high, desiccation and carbonization occur about the electrode, with cessation of deep penetration. Electrocoagulation can also, however, be effected by otherwise lessening the density of the cutting current (substitution of brush-discharge for true electric arc) through the use of electrodes of greater presenting area (hemostat, forceps, ball, etc.).

An ideal machine should furnish the foregoing amplitudes flexibly *at the electrode tip;* it should not include expensive, unnecessary and harmful voltages on its routine dials; it should have 250–300 ma. delivered capacity, most of which should be electively utilizable at below 200 volts. Its current should be smoothed free of harmonic faradic effects by a proper grid-leak type filter; its frequency should be low enough

* This takes distinct issue with (15), p. 1866, par. 4 and 5.

that (1) conduction delivery by clinically adequate cables is possible and (2) uninvolved metal clamps and retractors in the operative field do not warm; all parts of its circuits should preferably be grounded through supply wiring. A keyed Oudin coil for high voltage requirements might be available. The control panel should be horizontal and simple, and should have sturdy detachable boilable switch and dial-handles raised a decimeter above the panel surface. Many of the triode machines on the market today find difficulty in supplying adequate amperage without excessive voltage; and many gap machines, supplying adequate amperage, also include unused dial possibilities of redundant voltage. Finally, present cartel prices of most machines, in view of their actual equipment, wiring and labor, are excessive; and those of several of the pioneer machines remain prohibitive.

CONCLUSION

Electrosurgical incision is shown to be independent of frequency or wave form, and to depend upon current density. The characteristics and performance of an experimental unit, and several commercial machines, are examined; requirements of an ideal machine are deduced.

It is a pleasure to acknowledge the suggestion and guidance of Mr. H. R. Mimno, of the Cruft High Tension Laboratory, Harvard, in construction of the experimental unit; I am indebted to Professor G. W. Pierce for use of laboratory facilities there, and to Messrs. Carley and deYoung for their assistance. Dr. Richard Light kindly extended use of the Laboratory of Surgical Research, Harvard, and Misses G. E. Howard and M. L. Phillips assisted in the histology. The investigation was conducted under a grant from the DeLamar Mobile Research Fund, Harvard Medical School. The Children's Hospital, Peter Bent Brigham Hospital, and Mr. Charles H. Kehlenbach, were kind enough to allow temporary use of some of their electrosurgical devices. Wiring diagrams given depict the conditions in the machines investigated, and have been made independently of manufacturers literature in the rare instance where such information is published. Dr. George A. Wyeth, Dr. Grant E. Ward, and Mr. K. Stoye have been helpful with information and criticism.

REFERENCES

1. d'Arsonval, M. A. Methode nouvelle pour exciter electriquement les nerfs et les muscles. *Compt. rend. Soc. biol.*, 34: 244–45, 1882.
2. d'Arsonval, M. A. Action physiologique des courants alternatifs. *Compt. rend. Soc. biol.*, 43: 183–86, 1891.
3. d'Arsonval, M. A. Production des courants de haut frequence et de grand intensite; leurs effets physiologiques. *Compt. rend. Soc. biol.*, 45: 122–24, 1893.
4. Beer, E. Discussion of: Grant E. Ward's Advances in electrosurgery. *Arch. Phys. Therap., X-ray, & Rad.*, 12: 463–476, 1931.
5. Bell, W. H., and Ferguson, D. Effects of super-high-frequency radio current on health of men exposed under service conditions. *Arch. Phys. Therap., X-ray, & Rad.*, 12: 477–90, 1931.
6. Christie, R. V. and Loomis, A. L. The relation of frequency to the physiological effects of ultra-high frequency currents. *J. Exper. Med.*, 49: 303–321, 1929.
7. Clark, W. L. Oscillatory desiccation in the treatment of accessible malignant growths and minor surgical conditions: a new electrical effect. *J. Adv. Therap.*, 29: 169–183, 1911.
8. Clark, W. L., Morgan, J. D., and Asnis, E. J. Clinical and histological observations in the treatment of neoplastic diseases by combined methods. *Med. Herald & Physiotherapist*, 43: 271–75, 1924; 44: 10–12; 30–32, 1925.
9. Doyen, E. Sur la destruction des tumeurs cancereuses accessibles par la methode de la voltaisation bipolare et de l'electro-coagulation thermique. *Arch. d'élec. méd.*, 17: 791, 1909.
10. Gardner, G. H., et al. Studies on the pathological histology of experimental carbon tetrachloride poisoning. *Bull. Johns Hopkins Hosp.*, 36: 107–133, 1925.
11. Hosmer, R. Heating effects observed in a high frequency static field. *Science*, 68: 325–327, 1928.
12. Kovacs, R. Diathermy: its physics and clinical indications. *Med. J. & Rec.*, 124: 631–34, 1926.
13. Lamb, H. On the vibrations of elastic sphere. *Proc. Lond. Math. Soc.*, 13: 189, 1882.
14. Maupin, J. G. Electrical aspects of endothermy, with some surgical observations. *Arch. Phys. Therap.*, 7: 343–347, 1926.
15. McLean, A. J. The Bovie electrosurgical current generator: some underlying principles and results. *Arch. Surg.*, 18: 1863–1873, 1929.
16. Morton, W. J. On statical electrotherapeutics; or, treatment of disease by Franklinism. *Med. Rec.*, 19: 367–371, 395–398, 1881.

[For Remainder of References see p. 459.]

SKELETAL TRACTION & PRESSURE IN TREATMENT OF FRACTURES*

EDWIN A. NIXON, M.D.

SEATTLE, WASH.

INTRODUCTION

THE recognition of fractures and their treatment are subjects which have engaged the attention of medical practitioners in all ages, and the evidence of Egyptologists proves that many thousands of years ago broken bones were tied to splints in much the same way as they are today (Hey Groves).

With the increasing number of fractures, a toll for the more rapid means of transportation enjoyed in this age, we find altered methods of treatment offered in an effort to obtain a better percentage of good anatomical and functional end results than has been permitted by other means at our command. Skeletal traction has become a most popular method and the applicability, the efficiency, and the simplicity connected with its use sufficiently recommend it to the careful surgeon.

The object of this thesis is to review the treatment of fractures of long bones of the extremities as it has been carried out by various means of applying skeletal traction and pressure, on the Orthopedic Service at Harborview Hospital.

The combination of the methods of Codivilla, Steinmann and Becker is most popularly known now as the Steinmann pin method of skeletal traction. Our description and case reports has been limited to fractures in which the Steinmann pin was used for traction and also certain other cases for which specially devised apparatus was employed to exert pressure in lateral displacement of the fragments.

We have divided this paper into several sections:

(1) A review of the anatomy of the joints, with special reference to the application of metal traction and pressure apparatus

(2) Descriptions and photographs of methods and means by which skeletal traction and pressure have been applied

(3) Case reports, with photographs

(4) Summary.

ANATOMY OF THE JOINTS WITH REFERENCE TO THE APPLICATION OF SKELETAL TRACTION

Skeletal traction may be applied at the following sites:

1. To the os calcis
2. To the lower end of the tibia
3. To the upper end of the shaft of the tibia
4. To the lower end of the femur above the condyles
5. Through the olecranon process of the ulna.

There are less common sites for pin application but these locations will suffice for all fractures of the extremities except those of the forearm. Transfixion is not advisable at the lower end of the forearm bones because of the liability to inflammatory adhesions of the tendons around the wrist joint. Skeletal traction may be used in certain cases of fractures of the phalanges and then a small wire is preferable (Scudder).

OS CALCIS. The os calcis (Fig. 1) was one of the first bones to which skeletal traction was applied and this is quite efficient for the great majority of fractures below the knee. The pin is best applied under local anesthesia, at a point three

* From the Harborview Hospital, Seattle, Washington. Thesis submitted to the Faculty of Surgery of the Graduate School of Medicine of the University of Pennsylvania in partial fulfilment of the requirements for the degree of Master of Medical Science (M.Sc.(Med.)) for graduate work in Surgery.

fingers breadth below and behind the external malleolus, from without, inwards and at right angles to the bone. Owing to the late development of its bony structure, the os calcis is the only bone which cannot be satisfactorily employed for skeletal traction in children under twelve to fourteen years of age. The danger of injuring vessels, nerves or tendons in this location is negligible.

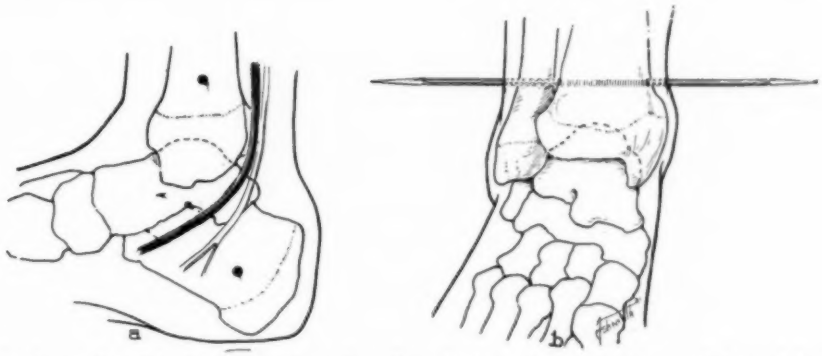


Fig. 1. A. Lateral view of ankle joint showing sites for placing pin through os calcis and lower end of tibia. B. Anteroposterior view of ankle joint showing pin through lower end of tibia.

Lower End of the Tibia. This site (Fig. 1) has become more popular of recent years for fractures which occur in the pelvic bones, femur, tibia or fibula in which skeletal traction is to be employed. The pin is applied from within outwards, at a point about two fingers breadth above the tip of the internal malleolus. The pin is inserted with the point directed outwards at right angles to the shaft of the tibia and following a plane which will make the point of exit slightly anterior to the point of entrance. The fibula is posterior to the pin and is not penetrated by it. The anterior and posterior tibial vessels and nerves to the foot will be avoided, but there is danger of injury to the tendons. The articulation of the astragulus with the tibia which causes a concavity in the lower end of the tibia is also avoided. The epiphysis which does not undergo complete fusion until the nineteenth year is safely avoided if this area is used in children.

Upper End of the Shaft of the Tibia. The pin is inserted just below the tibial tubercle and about two fingers breadth lateral to it (Fig. 2), thereby missing the epiphysis which does not unite with the shaft until about the twenty-second year of life. The fibula is posterior and is not penetrated at this site.

Lower End of the Femur. Skeletal traction is applied in this location by selecting a point on the mesial surface of the thigh just above the tip of the internal condyle or adductor tubercle (Fig. 2). Consideration must be given here for the lower epiphysis which unites with the shaft of the femur from about the twentieth to twenty-third year of life. The synovial membrane of the knee joint extends onto the femur, embracing approximately one third of the circumference of the shaft anteriorly, and must be carefully avoided to prevent joint complications. The popliteal vessels and nerves are in fairly safe territory. The introduction of the skeletal traction may be accomplished also, from the lateral surface just above the external condyle.

Olecranon Process of the Ulna. Occasionally fractures of the humerus may be more easily controlled by a pin through the olecranon process of the ulna (Fig. 3). The arm is flexed to a right angle and the pin or wire put through the olecranon just below the head of the radius and in front of a line drawn along the anterior border of the humerus. The joint cavity is avoided, the radial nerve is at a safe distance, and the important vessels are well anterior. The radius is not penetrated. The olecranon

process does not unite with the shaft until about the fourteenth year and should not be used before this age.

ether, and painting with iodine. The area is then anesthetized by injecting a sufficient quantity of 2 per cent novocaine at the

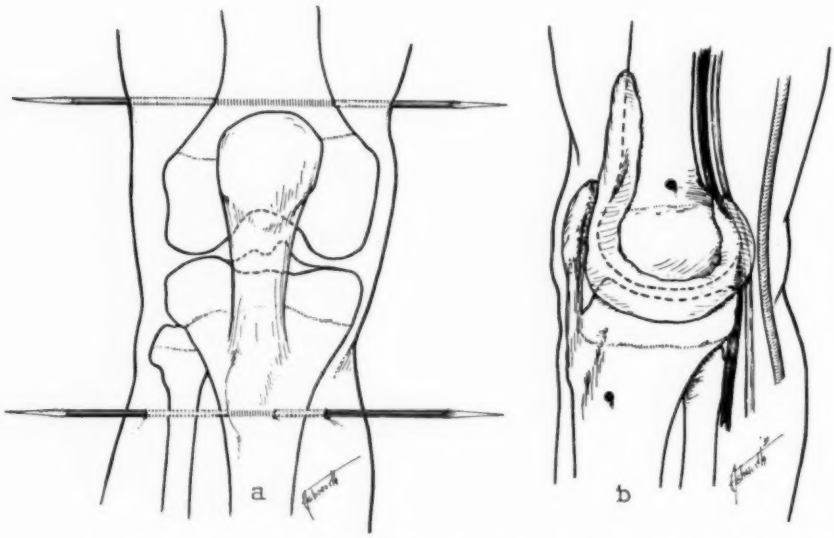


FIG. 2. A. Anteroposterior view of knee joint illustrating pin through upper end of tibia and lower end of femur. B. Lateral view of knee joint showing sites of pin application.

METHODS OF APPLYING SKELETAL TRACTION

STEINMANN PIN. The pin is a chromium plated solid rod, not divided, varying in length from 4 to 10 inches and having a diameter of $\frac{5}{32}$ of an inch (Fig. 5, A). The divided pin is constructed to permit the two ends to be separated by unscrewing it in the center and withdrawing each end. In this way there is claimed to be less chance for infection than when the solid pin is pulled back through the bone. These divided pins are weak and break in the middle portion. We have had no trouble with infection by using the solid pin and we have had the divided pin break under pressure so that we no longer use it. One end of the pin is sharp and the other dull, with bevelled sides to fit in a small handle (Fig. 4, B), with which it is pushed through the bone by a boring motion. The pin is prepared for use along with the other instruments, the ends of the pin being protected by placing corks over them.

The skin is prepared by shaving, washing with green soap and water, scrubbing with

point of entrance and exit of the pin. The site of fracture may also be injected with 20 to 40 c.c. of the same strength novocaine according to the method popularized by Böhler. Strict surgical asepsis must be maintained during this procedure and the technique must be faultless to prevent infection. The excess of iodine is carefully removed with alcohol to prevent skin burn, and dressings are applied over each end of the pin. Two gauze pads about 3 inches in diameter are used and held in place by twisting another larger pad over the pin ends. Sheet wadding is wrapped around the limb to keep the dressing close against the skin. It is not advisable to use gauze bandages or adhesive for this purpose because later swelling of the extremity may occur and the increased tightness of the tape or bandage may cause circulatory disturbances.

TIME AND MANNER OF REMOVING THE PIN. The time for removing the pin depends upon the age of the patient, the location of the fracture, callus formation and the occurrence of infection. Immobilization with skeletal traction is usually

continued a shorter time in children and a longer time in very old patients. If infection occurs, the pin is immediately removed and the infection treated locally. If callus formation is delayed, the pin is left in place for a longer time. In general the following schedule may be observed: fractures of the neck of the femur, twelve to fourteen weeks; fractures of the pelvis, four to six weeks; intertrochanteric fractures, seven to nine weeks; subtrochanteric fractures, six to ten weeks; fractures of the shaft of the femur, five to ten weeks; fractures of the tibia, four to twelve weeks; operative cases, four to fourteen weeks.

The patient is not aware of the presence of the pin unless told. Pin wounds never require redressing prior to removal of the pin. Practically all of our pins are embedded in plaster casts for rigid immobilization. If the cast is not removed at the same time decided upon for removal of the pin, a hole 3 to 5 inches in diameter is cut on each side of the cast around the pin. All sheet wadding and dressings are removed. Loose plaster is swabbed from the pin with the aid of sterile water and gauze pads. The protruding ends of the pin and skin areas surrounding them are cleansed with ether and iodine and the pin is pulled out with a pair of pliers. Sterile dressings are applied to each side of the extremity and they need not be changed for several days. Healing takes place within two weeks.

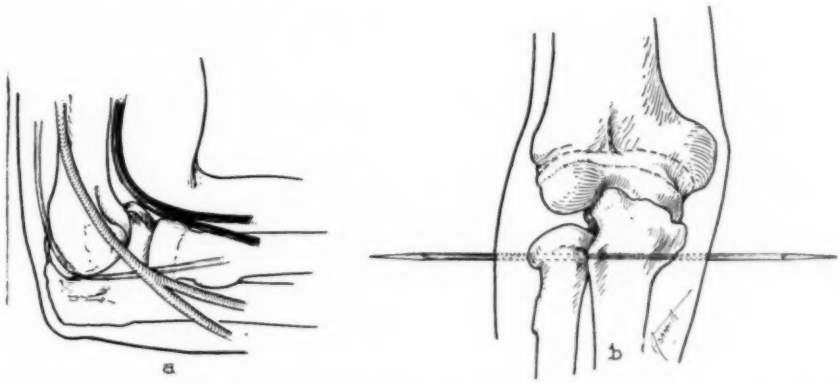


Fig. 3. A. Lateral view of elbow joint showing site for inserting pin through olecranon process of ulna. B. Antero-posterior sketch with pin in place.

"U" Stirrup. This device (Fig. 4, A) permits traction to be exerted on a Hawley table or by any other means available.

Fig. 4. A. "U" stirrup for traction, constructed so as to permit tips of pin to be slipped into either end of "U." B. Handle for manual insertion of pin.

After extension has been accomplished, the pin may be incorporated in a plaster cast which then maintains traction on removal of the stirrup.

Steinmann Pin Handle. This handle (Fig. 4, B) is used for manual insertion of

the pin. The bevelled tip of the pin is held firmly in the hollowed end of the handle while a boring motion is used for inserting

shortening, and in certain spiral fractures where reduction is difficult to maintain, the sliding sleeve type of pin may be

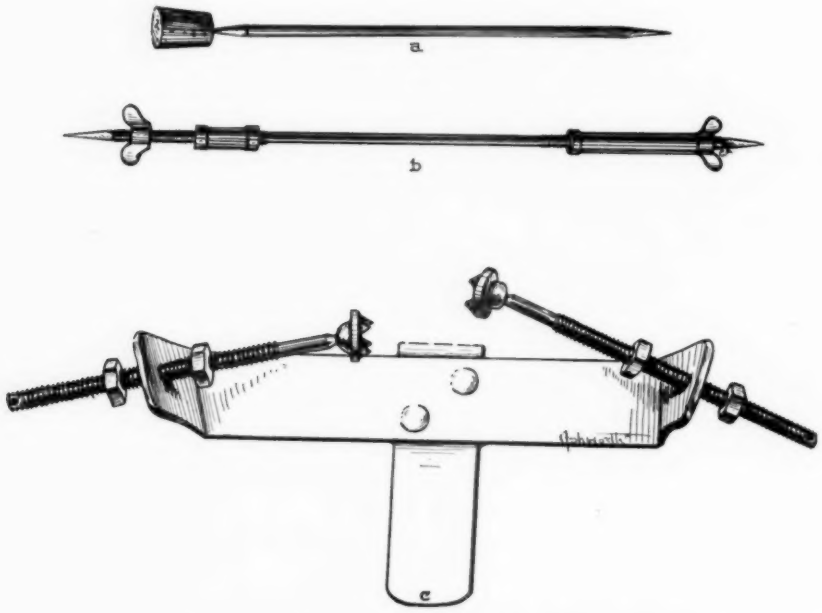


Fig. 5. A. Steinmann pin, sharp end protected by cork. B. Modification of Steinmann pin with sliding sleeves and wing nuts for exerting and maintaining lateral pressure. C. Lateral pressure clamp.

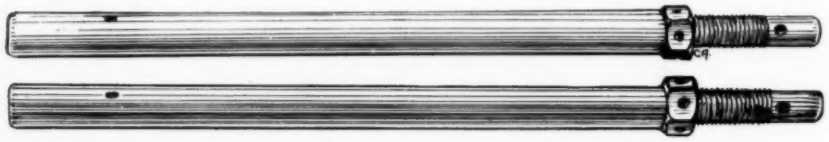


Fig. 6. Adjustable metal splints for use with double pin skeletal traction.

the pin.

Steinmann Pin with Sliding Sleeves. A modification of the Steinmann pin is shown in Figure 5, B, with threads on either end extending about one-third the length of the shaft. After the pin has been inserted in the usual manner, the sleeves are placed over the pin ends and pushed against the bone through small incisions in the skin. Pressure is applied and maintained by wing nuts screwed onto the pin. The pin was devised by Roger Anderson and used successfully in fractures where lateral pressure and traction are both necessary. Case IV represents the type of cases where this apparatus is of value. In general, where there is a lateral displacement as well as applied and buried in the cast for rigid immobilization.

Lateral Pressure Clamps. This apparatus (Fig. 5, C), also devised by Dr. Roger Anderson, was used to exert lateral pressure in a patient with a fracture of the head of the tibia. The pronged pressure points on a universal joint, attached to the adjustable rods, were placed against the bone fragments on either side through small incisions made in the skin. Pressure was exerted by placing a pin in the holes at the end of the rods and screwing them down. The pressure was fixed by nuts screwed onto the rods and placed on either side of the frame. The small incisions were closed with dermal suture and the entire appara-

tus was then incorporated by a plaster cast extending from beyond the toes to the upper thigh.

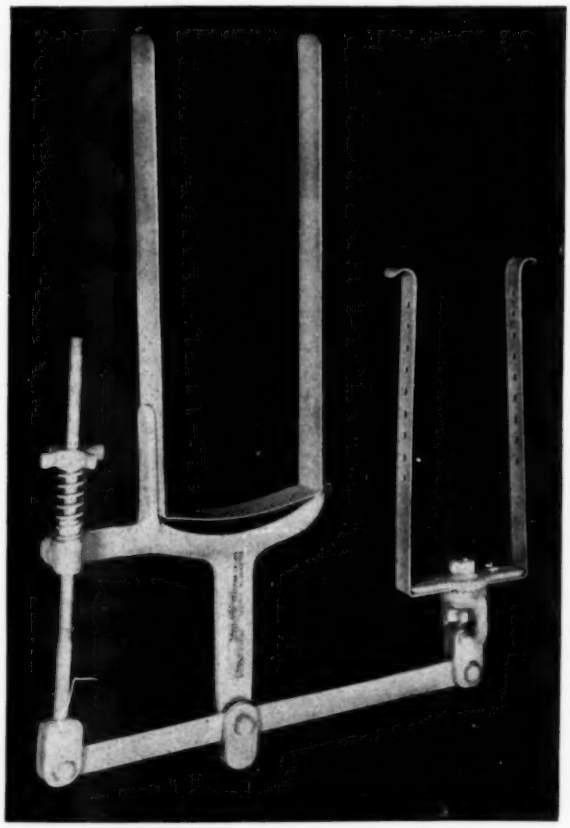


Fig. 7. Skeletal and well-leg countertraction splint (Roger Anderson).

Extension Bars for Double Pin Skeletal Traction. An apparatus was described by Abbott to aid in the fixation of bones in the leg following operative lengthening of the tibia and fibula. His suggestion has been utilized in the two bars, Figure 6, which permit the use of two pins for skeletal distraction. Each bar consists of a hollow metal tube 8 inches in length with a hole drilled transversely through the tube, ½ inch from the closed end. In the other end of the hollow tube was fitted a threaded rod, smaller in diameter but equally long, with a hole drilled transversely through its free end and with a nut for adjusting and fixing the length. These bars were used with two pins, one through the upper and one through the lower end of the tibia, and the bars were attached to the pins on each side. Distraction force was exerted by turning the nut on each bar and the fracture reduced. The pins but not the bars were incorporated in a plaster cast extending from the toes to the middle of the thigh. Should the fracture require manipulation later, a circular cut is made all around or half way around the cast in the plane of the fracture. Lengthening the distraction bar by turning the nuts on one

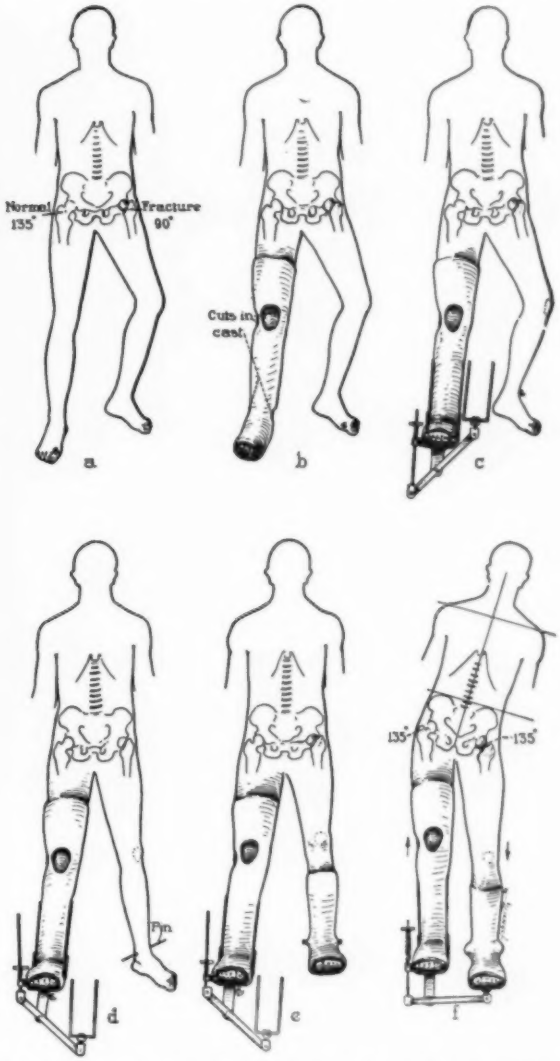


Fig. 8. Steps in routine application of well-leg countertraction splint. A. Before reduction in fracture of neck of left femur. B. Application of cast to mid thigh of well leg. C. Incorporation of splint in cast. D. Pin inserted through, tibia of injured leg. E. Pin incorporated in cast extending to knee. F. Splint attached, rotation adjusted, traction applied. Note angles at hips after reduction, with normal relationship maintained between pelvis and spine.

or both sides will overcome lateral displacement of the fracture. Tongue blades may be inserted in the cut in the cast if the bars are not used, and the same lateral displacement may be overcome. This procedure makes a v-shaped separation in the cast and is called "wedging." The cast is repaired with a few turns of plaster bandage around the cut. The use of these bars is further described and illustrated by Case v and Figure 12, B.

A B C D

Fig. 9. Case 11. A. Before reduction. B. After reduction with well-leg countertraction splint. C. One month later. D. Two months later.

Skeletal and Well-leg Countertraction Splint. This appliance (Fig. 7) was devised by Dr. Roger Anderson of Seattle. It is made of aluminum and weighs approximately 2 pounds. The essential parts are attached to a frame or base on one side of which is a countertraction stirrup, this being incorporated into the cast of the well leg. A transverse lever arm is pivoted on this stirrup, the axis of which is several inches distal to the sole of the well foot. On one side of the lever is connected a threaded rod, on which a nut, turned by the fingers alone, furnishes the traction force. A coil spring under the traction nut is for the purpose of maintaining a smooth, flexible and yet ever constant traction.

The opposite end of this lever arm, which is underneath the foot of the injured leg, is attached to a u-shaped band, the traction stirrup, with perforated holes ½ inch apart. The tongs, pin or wire are connected to this lever by special devices. The attachment for the use of pins is shown in Figure 7. The rotation of the fractured extremity is accomplished by a screw lock located at the base of the traction stirrup.

Technique of Application. This method of treatment is applicable to all fractures of the femur, including intertrochanteric and subtrochanteric fractures of the neck and fractures of the shaft; to fractures and injuries of the pelvis; and to certain fractures of the tibia. Moreover, it is a great aid in providing both traction and im-

mobilization for conditions of non-union or malunion and following reconstruction operations.

A B

Fig. 10. Case III. A. Fracture of lower third of left femur before reduction. B. Same, showing pin in femur, two months after reduction.

An *x*-ray examination requiring two views or stereoscopic films generally precedes treatment. The patient need not be taken from the cart on which he entered the hospital for either roentgenograms or the application of the splint.

A hypodermic or ⅛ to ¼ grain of morphine sulphate is usually given on admission to the hospital. Both legs are cleansed and any wounds dressed. All necessary manipulation should be done while an assistant makes gentle traction on the leg, in order to decrease pain and lessen trauma.

Nearly all of the injuries for which this method is applicable may be treated according to a standard routine. The following is an outline of the procedure. (Fig. 8, A–F.)

(1) Apply cast to mid thigh on well leg

(2) Incorporate splint in cast

(3) Insert pin through tibia

(4) Apply cast to injured leg, incorporating pin

(5) Incorporate splint in cast, exert traction, adjust rotation, complete reduction.

Application of Cast to Well Leg. The application of the cast is a very important procedure. First, stockinet is applied, then the leg is well padded with sheet wadding, especially in the region of the heel and ankle. A thin flexible piece of felt is applied to the sole of the foot. The leg is held in adduction, the knee in complete extension, the foot at right angle and the ankle in slight varus, while the plaster-of-

Paris cast is applied, extending from one inch beyond the toe-nails to mid thigh.*

Previous to the completion of the cast a thick reinforcement of plaster is applied to the sole of the foot, made thicker under and beyond the toes and over the plantar surface of the heel. To secure a balanced distribution of counterpressure throughout the plantar surface of the foot, that portion of the cast must be accurately moulded to fit the sole. The cast is cut out over both malleoli, and over the dorsum of all the toes. By the time these holes are cut, usually the plaster is set sufficiently to permit attaching the splint to the cast by a plaster bandage.† The base of the splint (Fig. 7) is set at a right angle to the longitudinal axis of the leg at a plane through the center of the malleoli, with an equal amount of space on each side, to avoid pressure by the splint on either malleolus. A space of at least a half inch must be preserved between each malleolus and each side of the countertraction stirrup.

A B

Fig. 11. Case iv. A. Comminuted fracture of lower end of left femur, before reduction. Anteroposterior view. B. Same, after reduction using Steinmann pin with lateral sleeves for pressure.

The technique of pin insertion has been described on page 445, and illustrated in Figure 4.*

Application of Cast to Injured Leg. The leg should be well padded with sheet wadding, especially over the malleoli and heel. A cast, incorporating the pin, is applied to the injured leg extending from one inch beyond the toe-nails up to a level 5 inches below the knee joint.† The sole of the foot is reinforced with plaster. Openings are cut in the cast over both malleoli.

The ends of the pin are then put through the perforations in the traction stirrup, the

*See Anderson,[4] Figure 6A.
†See Anderson,[4] Figure 6B.

*See also Anderson,[4] Figure 6C.
†See Anderson,[4] Figure 6D.

holes being selected which will enable the splint to be set up closely against the plantar portion of the cast. The pin ends are corked,

Correct rotary alignment is obtained by rotating the fractured leg internally or externally and is held by tightening the

A B

FIG. 12. Case V. A. Comminuted fracture of middle third of tibia and fibula. B. Same, after reduction, showing double pin distraction apparatus in place.

and both corks and stirrup are incorporated in the cast, preferably by a single plaster bandage.*

The next step is to exert traction by screwing down the traction nut. When the lever arm is at a right angle to the longitudinal axis of the well leg, sufficient traction has usually been exerted.

As traction displaces the acetabulum downward on the injured side, the patient prefers to lie on the bed with the upper part of the body toward the injured side, a position he should be encouraged to assume. From a cursory glance the pelvis may appear tilted, but closer examination clearly shows no abnormal relationship between spine and pelvis and consequently no danger of list or scoliosis, because the spine sets at right angles on the pelvis (Fig. 8, F). Abduction, therefore, is obtained in a physiological manner at the hip and not by a pathological list to the pelvis.

*See Anderson,[4] Figure 6E.

rotation nut at the base of the traction stirrup which was applied to the injured leg.*

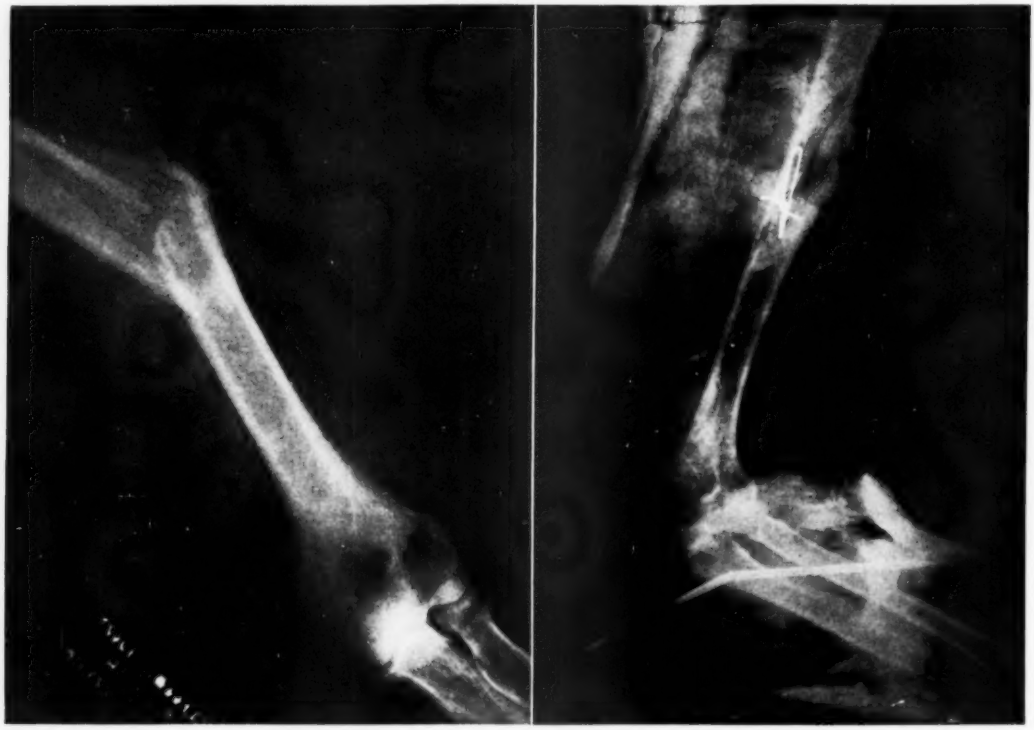
Reduction should now be checked by roentgenograms, traction and rotation being modified as indicated. If the plaster has set sufficiently the cast may be cut over the posterolateral aspect of the head of the fibula and also over the anterior surface of the knee joint. Usually this trimming of the cast is not done for several hours or until the next day and while the labor involved in cutting the cast is greater, the incidence of breaking and twisting of the cast is lessened. Occasional development of pressure points in these regions has made this a routine procedure.

The patient is not only permitted to sit up but is encouraged to do so and to use the trapeze freely; in a day or so he is able to raise himself up for toilet necessities. If the patient with a hip fracture is not in a

*See Anderson,[4] Figure 6E.

condition of shock, he will be permitted to use the wheel chair on the second or third day. Some patients, especially those with heart lesions, can safely be allowed to sleep in a semi-upright position. Patients with hip and intertrochanteric fractures may be turned on the abdomen daily. The greater part of the anterior portion of the cast of both legs may be removed, except for three transverse bands 2 inches in width.

After-care is at a minimum, for very little needs to be done except occasionally to cut out over the heel or to split the upper rim of the cast. The nurses and also the patients should be directed to massage and move the knee caps daily. It is advisable to repeat the roentgenograms as indicated. If the second plate reveals good position, the patient may be sent home. No attempt is made to dress the pin wounds until the time arrives for removal of the pins which will be from a few weeks up to a period of sixteen weeks, depending upon the location and type of injury.



A B

FIG. 13. Case VI. A. Comminuted fracture of middle third of right humerus before reduction. B. Same, after reduction, bone ends wired together and alignment maintained by pin through olecranon.

CASE REPORTS

CASE 1. E. H., female, aged eighty years. *Diagnosis:* Extensively comminuted intertrochanteric fracture of the neck of the right femur, with the lesser trochanter displaced slightly mesial.*

Patient was a senile individual from whom an adequate history was not obtainable. She had apparently fallen on the floor of her home and injured her leg.

Because she was unable to cooperate, a few drops of anesthol were administered and the well-leg countertraction splint applied with a cast on the left leg extending to the thigh. The cast was cut out over the malleoli and the head of the fibula, as it has been noted that these are the most common locations for pressure symptoms to develop. A Steinmann pin was put through the lower end of the right tibia in the usual manner, a few hours after her admission to the hospital. This was three days after the accident had occurred.

The patient is still in the cast seven weeks after the accident, able to be moved about,

* See Anderson,[4] Figure 10.

sitting propped up in bed, and in every respect comfortable and easily cared for by the nurses.

Case II. J. P., male, aged thirteen, weight 90 pounds.

Diagnosis: Complete fracture of middle third of the left femur with approximately 2 inches shortening (Fig. 11).

The patient was injured by a fall from a horse and he was unconscious for a few moments, after which he was unable to move his left leg.

Twenty cubic centimeters of 2 per cent novocaine were injected into the fracture site. Another small amount of novocaine was injected into the lower end of the left femur and a Steinmann pin was inserted at this point. The well-leg countertraction splint was then applied. The casts on both the well and injured leg extended to the upper thigh. The splint, pin and casts were removed at the end of five weeks. He was seen for the last time at the end of two months and was bearing his weight on the extremity. There was no apparent or real shortening and the functional results were excellent.

Case III. J. S., male aged thirty-six.

Diagnosis: Complete fracture of the lower third of the left femur with the distal fragment displaced posteriorly. Plates of the pelvis showed what appeared to be an old bilateral deformity of the femoral necks due to Perthes' disease (Fig. 10).

The patient was struck by an automobile. He complained of pain and inability to move the left thigh and also of some pain in both hips.

Under local anesthesia, the well-leg countertraction splint (Fig. 7) was applied. The cast was first put on the right leg up to the middle of the thigh. A Steinmann pin was put through the lower end of the left tibia and another pin inserted through the left femur above the condyles. The purpose of the pin through the femur was to overcome the pull of the gastrocnemius muscle, not possible by direct extension when the fracture is in the lower third of the shaft of the femur.

The technique has been altered in the last few cases only one pin being used through the lower end of the femur and none through the tibia. Traction was exerted by attaching the leg to the Hawley table and anterior traction was made on the pin. A cast was applied from the ankle to the upper portion of the thigh after reduction of the fracture and after it had set, the cast was continued down over the toes and the well-leg countertraction splint applied. This method necessitates the use of only one pin.

Both pins, the splint and casts will be removed at the same time after about nine weeks of immobilization.

Case IV. L. K., negress, aged forty-nine.

Diagnosis: Comminuted supracondylar T-fracture of the left femur extending into the knee joint (Fig. 11).

The patient was riding on the back seat of an automobile when the machine struck something and she was thrown out, injuring her left leg.

Treatment was instituted by putting the patient on a Hawley table and applying traction to the left leg. A Steinmann pin with adjustable sleeves (Fig. 5, B) was inserted through the distal fragments of the fractured femur and lateral pressure was added to traction to effect reduction. A unilateral hip spica was then applied from the toes to the chest, incorporating the pin in the cast to fix the fragments after reduction.

Case V. A. Mc., female, aged forty-six.

Diagnosis: Comminuted fracture of the middle third of left tibia and fibula. (Fig. 12).

The patient fell from a ladder a distance of 12 feet.

Under nitrous oxide anesthesia, a Steinmann pin was inserted through both the upper and lower ends of the left tibia. The lateral adjustable metal splints (Fig. 6) were then applied. Reduction was checked by *x*-rays and the cast applied from the toes to the mid thigh, incorporating both pins. The position was checked by subsequent roentgenograms and the patient permitted to return home.

The pins and cast were removed at the end of nine weeks. The functional and anatomical results were excellent.

The use of these splints is similar to the method suggested by Abbott in his operative lengthening of the tibia. Pitkin and Blackfield also reported a series of 12 cases in which a similar treatment was instituted.

Case VI. E. S., female, aged seventy-four years.

Diagnosis: Comminuted fracture of middle third of the right humerus (Fig. 13).

The patient was in an automobile accident in which the car turned over, injuring her right arm.

She was an obese female of short stature and attempts at closed reduction with cast application failed to get good alignment on two attempts.

Ten days later, under nitrous oxide anesthesia, an open reduction was done. The bone ends were approximated and held in position by braided wire. The wound was closed. Because of the earlier difficulty encountered in holding the arm in satisfactory position while applying the cast, a divided Steinmann pin was put through the olecranon process of the right ulna. Traction was maintained through the medium of this pin, which was embedded in the cast. Nine weeks later the cast was removed. Following physiotherapy, the function in the arm returned quite satisfactorily. Flexion was about 75 per cent of normal.

The divided pin broke in this case and this experience has militated against its future employment in our hands, for reasons given earlier in the paper.

SUMMARY

In the foregoing case reports of fractures in the long bones where traction was needed, the Steinmann pin method was used. This has been so satisfactory in our hands that change to another method is deemed unnecessary. The cost is minimal as there is no expensive equipment to purchase. A pin may be put in place with instruments requiring an outlay of but a few dollars, and subsequently only a few cents for each pin.

There has been no instance of osteomyelitis developing in our series of about 70 cases in which pin traction was employed. Roger Anderson has not had a bone infection during a five-year period in which he used the pin for skeletal traction. Should a draining sinus persist, it may be easily curretted, as was suggested by Conwell who uses a pin in severe compound fractures in patients engaged in coal and iron mine work. By the use of strict surgical asepsis, there is reasonable assurance that the wound will not become infected. We have never employed preliminary drilling, as has been the custom in some localities.

The popularity of the piano wire type of traction and the feeling that infection is less likely to occur are due in a measure to the sense of security existing with a small hole in the bone as contrasted with a slightly larger one produced by the pin. It would seem reasonable to assume that there was no greater danger in the larger diameter of wire for skeletal traction, than in a larger incision for abdominal exploration, for infection may occur in either instance, due to faulty technique. Emphasis must be placed, however, on avoiding the changing of dressings around the pin. Care must be exercised also in removing the pin and frequently one will note a small amount of serum following the withdrawal of the pin. The serum has been cultured and found to be sterile and subsequent complete healing of the wound has confirmed the bacteriological finding.

The dangers of slipping and cutting the bone by the wire are as great as, or greater than, in the use of the pin. Burkle reports several cases in which the wire did cut the bone and result in a suppurative arthritis requiring amputation.

Plaster-embedded skeletal traction as advocated by Orr and Thomson, and Speed, which we have used almost exclusively, practically precludes the complication of skeletal traction slipping and cutting the bone. Fixed traction also minimizes the percentage of non-union of fractures.

It has been held that traction through a joint weakens its ligaments, and if disproportionate force is exerted on the ligaments of a patient who has been weakened by muscular disuse and sepsis a joint injury is likely to result. Judgment and experience will obviate employment of traction through a joint when the surgeon finds these contraindications to exist. Hey Groves feels that ligament stretching is practically negligible, but on the other hand distraction of the joint surfaces produced by extension affords a valuable

factor in maintaining the mobility of the joint, particularly so in the elbow and ankle. When there is a fracture near any joint, stiffness of the articulation is a great danger to be feared and guarded against. On the other hand flail joints are unknown following traction through a joint, except in paralytic conditions or cases where a large amount of bone has been lost. Physiotherapy after the fracture has healed readily overcomes joint stiffness from disuse.

Pain at the site of the pin is a rare complication. Usually the patient is not aware of the presence of the pin unless told about it. Reduction of swelling and the resulting looseness of the pin in the cast may cause pain unless the cast is changed and rigid fixation maintained by means of a new cast.

CONCLUSIONS

Skeletal traction with Steinmann pins is a most reliable and efficient method for treating fractures.

Embedding the pins in plaster casts, as we have done in all of our cases, makes for a true fixed dressing with immobilization in correct position as an accomplished fact.

Rigid fixation of pins in plaster is less provocative of bone cutting and infection than constantly shifting of pins when weights, ropes and pulleys are used.

The undivided or solid Steinmann pin is empirically safe. Five years in private practice and two years' experience on a county hospital service, where the responsibilities of the house staff are greater, and with only a single incidence of infection, either before or after removal of the pin, are proofs against adverse criticism.

The modified Steinmann pin with adjustable sleeves for lateral pressure and the special clamps for the same purpose are of great value in reducing and maintaining the position of laterally displaced bone fragments, especially when the fracture extends into a joint.

The well-leg countertraction splint employing skeletal traction for the injured leg is an original splint devised by Roger Anderson. The splint has been used successfully for dislocation of the pubic bone, for injuries and fractures of the pelvis, for fractures of the neck and shaft of the femur, and for fractures of the tibia.

My appreciation is due Dr. Donald V. Trueblood, who sponsored this thesis as my preceptor.

REFERENCES

1. Abbott, Le R. C. Operative lengthening of the tibia and fibula. *J. Bone & Joint Surg.*, 9: 128–152, 1927.
2. Anderson, Roger. New method of employing skeletal traction. *Northwest Med.*, 30: 444–448, 1931.
3. Anderson, Roger. New method for treating fractures, utilizing the well leg for countertraction. *Surg., Gynec. Obst.*, 54: 207–219, Feb. 1932.
4. Anderson, Roger. Well-leg countertraction method: details of technique. Am. J. Surg., n.s. 18: 36, Oct. 1932.
5. Becker, E. Extension on bones by boring through them. *Zentralbl. f. Chir.*, 35: 1417–1420, part 2, 1908.
6. Böhler, L. Modern treatment of fractures of bones. *Wien. klin. Wchnschr.*, 43: 596–596, 1930.
7. Burkle-de-la Camp, H. Word of caution in regard to use of clamp and wire extension apparatus in treatment of fractures of extremities. *Deutsch. Ztschr. f. Chir.*, 223: 178–181, 1930.
8. Codivilla, A. On the author's method of traction extended directly to the skeleton. Extension by nails. *Ass. franc. de chir. Proc. verb. (etc.), Par.*, 23: 763–768, 1911.
9. Conwell, H. E. Treatments of severe injuries of the leg by traction with the Steinmann pin through the os calcis. *J. Bone & Joint Surg.*, 10: 268–283, 1928.
10. Fitzgerald, R. R. The Kirschner method of skeletal traction in the treatment of fractures. *Canadian M. A. J.*, 24: 83–87, 1931.
11. Hey Groves, E. W. Direct skeletal traction in the treatment of fractures. *Brit. J. Surg.*, 16: 149–157, 1928–1929.
12. Hey Groves, E. W. Modern Methods of Treating Fractures. N. Y., Wood, 1922.
13. Orr, H. W., and Thomson, J. E. M. End results to illustrate the value of fixed traction in the treatment of fractures of the lower extremity. *J. Bone & Joint Surg.*, 7: 696–708, 1925.
14. Orr, H. W., and Thomson, J. E. M. Maintaining length and position in the treatment of compound fractures. *J. A. M. A.*, 83: 1399–1403, 1924.
15. Pitkin, H. C., and Blackfield, H. M. Skeletal immobilization in difficult fractures of the shafts of the long bones. *J. Bone & Joint Surg.*, 8: 589–594, 1931.
16. Scudder, C. L. The Treatment of Fractures. Phila., Saunders, 1927, pp. 217–231.
[For Remainder of References see p. 477.]

MULTIPLE OSSIFICATION CENTERS OF THE PATELLA*

PAUL W. GREELEY, M.D.

WINNETKA, ILL.

ALTHOUGH the error of making the diagnosis of fracture in multipartite patellae was more common before the days of Roentgen, nevertheless the confusion still exists in many instances.

On account of its development and anatomical location, the patella is usually considered a sesamoid bone.[1] Commonly it ossifies from a single center in the second or third year of life though occasionally not until the fifth or sixth. These centers normally close by the age of twelve or fourteen. However, one may find two, three, or even more centers of ossification and in such instances these separate parts may never fuse, and are then held together by a fibrous union. The earliest description of this condition is that made by Wenzel Gruber[2] of Petrograd in 1883. He believed that owing to inhibition of growth processes, these centers fail to fuse into a single patella. Following this author there were several brief accounts in the literature until 1921, when Dr. Sindling-Larsen[3] recorded what he believed to be a new clinical entity.

In two otherwise healthy girls of ten and eleven years, respectively, who after overstraining themselves by dancing and jumping had complained of pains in their knees. When the patients were seen by the author, the affection was in each case unilateral; the pole of affected patella was painful on pressure and in one of the cases the soft parts over and below the patella were slightly swollen. In the roentgenograms of the knees taken in profile, the anterior and lower outlines of the painful patellae were hazy with abnormal calcium deposits or bone shadows in the periosteum below the patellar apices.

The author interpreted these findings as indicating epiphysitis caused by overstrain, and offers in support of his conclusions the finding of a mild Schlatter's disease of the tibial apophysis in one case. The roentgenograms of the healthy knee in both cases showed similar abnormalities in a lesser degree. The first case was treated by plaster immobilization for six weeks; the second, with rest without fixation. In each case a complete recovery both clinically and roentgenologically resulted after six months treatment.

In 1922, Dr. Sven Johansson,[4] unaware of Larsen's paper, reported the same condition. He records four cases. Each of these patients made a prompt recovery after the knee had been relieved from strain for a month or two.

Kempson[12] in 1902 pointed out that the usual accessory center of ossification occurs at the outer margin of the patella. In 1921, McNally,[13] in a study of a large series of patellae taken from cadavers, found that 3 per cent had a more or less marked defect at the upper outer margin of the patella with or without a true accessory center of ossification at this site. He found that such defects were bilateral in two-thirds and unilateral in one-third of the cases. Of special interest was one with a definite partially fused separate center of ossification at the attachment of the patellar ligament to its lower pole.

Hawley and Griswold[5] believe that both Larsen's and Schlatter's disease are essentially traumatic, resulting from a strain of the patellar ligament which is in itself potentially strong, but in both Osgood-Schlatter's a nd Larsen-Johansson's disease, is attached below or above into a weak point of anchorage.

Buttner[6] describes a case of Perthe's disease and tripartite patella in a girl of eleven years. The child was born with bilateral club feet. There was no evidence of rickets. She learned to walk at the age of one. About one year previous to the report pain in both hips and knee joints developed without fever. After a failure

* From the Department of Surgery, Northwestern University Medical School, Chicago.

with medical treatment the patient was admitted to the hospital. The blood Wassermann reaction was negative. There

Fig. 1.

Fig. 2.

was a moderate lymphocytosis. Both thighs flexed to about 40 degrees at the hip joints and there was a corresponding lordosis of the spine, especially in the lower dorsal portion. The trochanters were elevated on both sides. The knee joints were thick but movable. There was an abnormal amount of lateral mobility, especially on the right. *X*-ray examination of Buttner's case revealed a bilateral Perthe's disease of the hip joints. The roentgenograms also revealed multiple deformities of the skeletal system. He states that the peculiar condition of the patella, in which three ossification centers were seen, could not be found referred to anywhere in the literature (1925).

Fleischner reports a unilateral case with a Schlatter's disease of the other side.

Odermott[8] believes that lateral accessory ossifications occur along the patella proper. It is uncertain whether an ontogenetic triple division can also be assumed. The regularity and similar shape of the three parts would seem to support such a theory. His case presented a manifold complication of skeletal deformities, including:

1. Rarefactions of the skull
2. Flattening of the vertebrae
3. Flattened epiphyses
4. Joint surfaces of the elbow flattened
5. Flattened epiphyses of the hand joints
6. Marked flattening of the distal epiphyses of the metacarpals
7. Flattening of the epiphyses of the femoral head
8. In both knee-joints, the epiphyses of the femur and tibia were flattened
9. The patellae were tripartite on both sides
10. Bilateral flattening of the lower tibial epiphyses
11. Bilateral bone atrophy at the distal end of the first metatarsals. With such an

array of pathology in one case, there is ample need for further investigation of epiphyseal disease from the standpoint of constitution, heredity and degenerative stigmata.

Reinbold[7] reports a case of unilateral tripartite patella in a man of twenty-four years. He twisted his left knee in descending the stairs and developed a hydrarthrosis. *X*-ray examination revealed three centers of ossification in the patella detached from one another. The patient gradually recovered the full use of his joint and the patella condition was therefore not attributed to the slight trauma.

Odermott[8] distinguishes three anomalous types of patella:

1. Division by a horizontal cleft in the lower third or fourth
2. Lateral development of one or more accessory fragments
3. The most frequent development is in the upper lateral quadrant of one or more accessory fragments.

Odermott[8] describes another case in a man of fifty-eight, who had suffered a fall on his right knee. Roentgenograms showed several fragments, partly with smooth opposing surfaces in the upper quadrant of the patella. The fragments completed the normal shape of the patella. The left patella was normal. At operation two larger and several smaller bones were found. The opposing surfaces of the larger fragments were smooth. In the smaller fragments, roentgen examination revealed rarefactions which histologically proved to be genuine bone marrow spaces. From the histologic study, it seemed probable that this was a case of non-fusion of multiple osseous nuclei. In other words an anomalous development of the patella.

I report the following case:

Mr. W. L. aged fifty-five years, entered the Northwestern University Medical School Surgical Dispensary on February 25, 1931. He was complaining of a swollen, red, tender area, about 4 inches in diameter, on the anterior aspect of the right leg. This was obviously a cellulitis, which on further questioning was found to have followed the scratching of a louse bite, with which he was copiously infested. In making a complete examination, it was noted that each knee was peculiarly deformed, although there was no loss of motion or subjective weakness in either. He stated that he had had each knee operated upon "because the knee caps were pulled apart." No other reason for operation could be elicited from the patient.

The right knee had been operated upon in July, 1907, at which time the fragments were sutured together with catgut. A posterior extension of splint was worn for one month. The segments of the patella again pulled apart after one year.

The left knee was operated upon at another hospital in February, 1912. This time steel wire was used to suture the fragments, after which a posterior retention splint was worn for two weeks. The fragments of the left patella at the time of this examination, although somewhat close in apposition, were readily moved apart and laterally on palpation.

Owing to the intervening length of time since the operations, the previous hospital records had been destroyed, so it was consequently impossible to procure a more accurate check on this case.

The *x*-ray film shows two large and two small fragments of the left patella. The right shows a main piece, consisting of perhaps three-fifths or two-thirds of the patella, riding high up above the lower end of the femur. The rest of the patella is found in two pieces. The separation is much more marked in the right knee. There is also seen a fabella in the long head of the gastrocnemius on the left side. (Dr. James T. Case.)

Of the recorded cases, one finds multiple centers of ossification in about 15 per cent of the number. These do not necessarily mean a divided patella however, as they may fuse to form a normal patella. Among 410 knee roentgenograms, Odermott found 15 bipartite or multipartite patellae.

The deformity may give rise to no symptoms, or by fracture of the parts lead to arthritic symptoms. The soft tissues separating the fragments may become injured, stretched or torn, leading to swelling and pain of the knee joint, and eventually to a false movability of the

fragments in relation to each other. The distortion may heal or lead to symptoms resembling a chronic arthritis. The usual therapy for joint effusions or arthritis is indicated in such cases.

Operative removal of the fragments is indicated only in case of chronic irritation, and suturing of the larger pieces together only if there is a weakness of the knee joint. This latter is usually one of inability to completely extend the leg.

In compensation cases, these injuries play a significant part and must be differentiated from fracture.

Inasmuch as this condition seems analogous to Schlatter's disease of the tibia, it should, when recognized in early adolescent life, be treated so as to keep as much strain as possible away from the patella. By this means the separate centers may thereby have some chance of fusing together.

REFERENCES

1. Prentiss and Arey, L. B. Text Book of Embryology. Ed. 3, p. 316.
2. Neviaser, J. S. Bipartite patellae. *Ann. Surg.*, 94: 150, 1931.
3. Larsen, S. En hittel ukjendt sygom i patella. *Norsk. Mag. f. Laegeidensk.*, 82: 856–858, 1921.
4. Johansson, S. En fornt icke beskriven sjukdom i patella. *Hygiea*, 84: 161, 1922. Eine bisher auscheinend unbekannte Erkrankung patella. *Ztscbr. f. orthop. Cbir.*, 43: 82, 1924.
5. Hawley, G., and Griswold, A. Larsen-Johansson's disease of the patella. *Surg., Gynec. & Obst.*, 47: 68, 1928.
6. Buttner, G. Zur Atiologie und pathogenese der Perthesschen Krankheit (Zugleich ein Fall von Patella tripartita.) *Arcb. f. klin. Cbir.*, 136: 703, 1925.
7. Reinbold, P. Le rôle des anomalies d'ossification de la rotule dans le diagnostic de lesions tramatiques de genu. *Rev. mèd. de la Suisse Romande*, 37: 653, 1917.
8. Odermott, W. Zwei-und Mehrteilung der Patella. *Scbweiz. med. Wcbnscbr.*, 51: 1263, 1921.
9. Cunningham. Text Book of Anatomy, Ed. 5, 1919, p. 245.
10. Gray, H. Anatomy of the Human Body. Ed. 20, 1918, p. 256.
11. Whitman, R. Orthopedic Surgery. Ed. 8, 1927, p. 470.
12. Kemson. Emargination of the patella. *J. Anat. & Physiol.*, 36: 419, 1902.
13. Todd and McNally. Defects of the patellar border. *Ann. Surg.*, 64: 775, 1921.

REFERENCES OF DR. MCLEAN*

17. Morton, W. J. A new current of induction electricity, or a new method of producing electrical nerve and muscle reaction. *Med. Rec.*, 20: 62–63, 1881.
18. Morgan, J. D. Electrothermic Methods in the Treatment of Neoplastic Diseases. Phila., Davis, 1926, pp. 172.
19. Nagelschmidt, F. Zur Indikation der Behandlung mit Hochfrequenzströmen. *Deutscb. med. Wcbnscbr.*, 33: 1025–26; 1289–91, 1907.
20. Pozzi. Remarques sur la fulguration. *Bull. de l'assoc. franc. p. l'étude du cancer*, 2: 64–69, 1909.
21. Riviere, A. J. Action des courants de haute frequence et des efflures du resonateur Oudin sur certaines tumeurs malignes. *J. de med. interne*, 4: 776–777, 1900.
22. Schereschewsky, J. W. The physiological effects of currents of very high frequency (135,000,000 to 8,300,000 cycles per second). *U. S. Pub. Healtb Rep.*, 41: 1939–1963, 1926.
23. Schereschewsky, J. W. The action of currents of very high frequency upon tissue cells. *U. S. Pub. Healtb Rep.*, 43: 927–945, 1928.
24. Ward, G. E. The present status of electrosurgery. *Am. J. Surg.*, n.s. 6: 230–233, 1929.
25. Woodbury, F. T. Therapy with high frequency electromagnetic energy: introductory resume of situation from Morton to Schereschewsky. *Pbys. Tberap.*, 47: 37–48, 1929.
26. Wyeth, G. A. Endothermy, a surgical adjunct in accessible malignancy and precancerous conditions. *Surg. Gynec. Obst.*, 36: 711–714, 1923.
27. Wyeth, G. A. The endotherm. *Am. J. Electrotherap. & Radiol.*, 42: 186–187, 1924.
28. Wyeth, G. A. Surgery by Electrothermic Methods. N. Y., Hoeber, 1927.

*Continued from p. 441.

SURGERY OF THE SYMPATHETIC NERVOUS SYSTEM

WALTER D. ABBOTT, M.D.

DES MOINES, IOWA

THE recent advances in surgery of the sympathetic nervous system have stimulated widespread interest because certain types of disease, hitherto resistant to other forms of treatment, have been relieved. It is the purpose of this paper to present the type of disease condition which will favorably respond to sympathectomy and to outline briefly the method of selection of cases and the operative procedures.

HISTORICAL SURVEY

The first sympathetic ganglionectomy was performed by Alexander in 1899 when he removed both superior cervical ganglia for epilepsy; in 1896 Jonesco divided the trunk above and below the middle cervical ganglion for epilepsy and a year later repeated this operation for exophthalmic goiter. Franck's discussion in 1898 lent new interest to the sympathetic system when he considered that angina pectoris was the result of an overflow of painful impulses reaching the cord via the stellate ganglion. Over thirty years later Ransom corroborated Franck's view by stating that sensory fibers carry impulses to the spinal cord through the white rami.

In 1899 Jaboulay cut the nerves approaching an artery and Higier, 1901, recommended tearing the nerve plexus around the femoral artery in cases of intermittent claudication. Leriche, who is oredited with the establishment of periarterial sympathectomy, reported two cases of causalgia in median nerve injuries in which he resected the sheath of the brachial artery in 1917. Since then he has reported large series of cases with favorable results lasting from a few months to several years. Leriche advocates periarterial sheath resection in all cases of vasospastic disorders, such as Raynaud's disease, causalgia, trophic ulcers and the superinduced spasm of the collateral vessels in thromboangiitis obliterans, as he believes there is an intramural ganglion in the arterial wall. However Kramer and Todd and Potts and Kuntz have demonstrated that the sympathetic innervation of the peripheral vessels corresponds to the musculocutaneous distribution of the spinal nerves.

Hunter and Royle, 1924, reported beneficial results from ramisectomy in cases of spastic paraplegia, and at that time noted the extremities operated upon were warm, dry and pink. Adson and Brown, utilizing this knowledge, applied it to Raynaud's disease, and in 1924 reported the first cases of lumbar sympathetic ganglionectomy and ramisectomy with brilliant results. Adson prefers the transabdominal route because it is possible to see the inconstant rami emerging from the first lumbar ganglion, which would be missed by the retroperitoneal approach.

The anterior approach to the stellate ganglion for vasospastic conditions in the upper extremities was not very successful until in 1928 Adson devised the posterior approach following the suggestion of Henry.

In the past decade a number of surgeons have utilized either sympathectomy or alcohol injection of the sympathetic ganglia for various types of intractable pain. The work of Swetlow, White and Mixter in relieving the pain of angina pectoris, Archibald and Scrimger and Verbrugge and von Bogaert in alleviating abdominal pain and Stern in relieving the distress of thromboangiitis obliterans has been particularly outstanding. Later Adson, Rowntree and Henderson reported marked benefit in certain cases of arthritis when sympathectomy was performed. More recently Flothow and Abbott have reported cases of

intractible pain in various regions of the body which have been alleviated by alcohol injection of the sympathetic nervous system.

DISEASES AMENABLE TO SYMPATHECTOMY

Raynaud's Disease. This is a classic vasospastic condition and is characterized by a bilateral symmetrical vasoconstriction of the hands and feet. Little has been added to Raynaud's original description when he observed that there is a form of gangrene of the extremities without any evidence of vascular occlusion. This phenomenon varies in degree to such an extent that many cases of mild vasoconstriction are confused with Raynaud's disease. These patients complain of a coldness of the hands and feet, some blanching of one or more digits and a moderate amount of pain when exposed to the cold. Although there is no contraindication to surgery in these cases, it seems a drastic procedure when relief may be obtained by the application of external heat, massage and wearing warmer clothes.

True Raynaud's disease is characterized by the presence of symmetric color changes in the extremities, either upper or lower. The knees, elbows, ears and tip of the nose may also be involved in severe cases. The blanching of the skin is induced by exposure to the cold or emotional influences, and this is followed by cyanosis until the vasospasm subsides. The gangrene of Raynaud's disease is dry and occurs at the tips of the fingers and toes with distortion of the growth of the nails, instead of complete gangrene of a digit as seen in occlusive vascular disease.

Raynaud's disease is chiefly seen in women and few cases in men prove to be a pure vasoconstriction without at least some changes in the lumen of the artery. The surgical procedure carries no more risk than a laparotomy and the relief from pain is well worth that small risk. Immediately after operation the fingers or toes are free from pain and are warm, dry and pink. The trophic lesions soon heal and the nails rare restored to normal growth. The Horner's syndrome following cervico-thoracic sympathectomy consists of a constriction of the pupil, narrowing of the palpebral fissures and an absence of perspiration over the face. The retinal vessels are dilated and the caliber of the capillaries of the mucous membrane of the nose is enlarged so that there is an increase of mucous secretion. The skin is usually quite dry after operation but the application of cold cream or cocoa butter is sufficient to relieve this slight discomfort which is nothing in comparison to the previous pain from vasoconstriction.

Scleroderma. This is a disease of the skin characterized by pigmentation, thickening or atrophy, and is frequently associated with sclerodactylia. The distribution is inconstant but is usually confined to the extremities, face, neck and chest, although the entire trunk may be involved in severe cases. Muscle and joint action may be limited in this condition. Not all cases of scleroderma are caused by vasoconstriction but many patients in this group give a history of cold, clammy cyanotic extremities prior to the skin changes. This type of case responds to the sympathetic ganglionectomy as the extremities become warm, dry and pink and there is a gradual loosening of the tight skin.

Causalgia. This is a painful condition following injuries to the peripheral nerves, chiefly the ulnar, median and sciatic nerves, and is characterized by pain, glossy, red or mottled red and white skin and limited joint motion. Sympathectomy or alcohol injection of the sympathetic ganglia has offered relief in a number of cases, however the psychic and compensation element is often a paramount factor in this type of disease.

Arthritis. There is a small group of young adults who have painful, swollen, tender joints, limited motion and cold, clammy extremities. External heat gives a moderate degree of relief and when typhoid vaccine is administered intravenously there is an increase in the temperature of the extremities with a temporary relief from pain. A permanent result is obtained by

sympathectomy but extreme care must be exerted in the selection of cases.

Thromboangiitis Obliterans. This condition is due to an occlusion of one or more of the main arteries to an extremity associated with varying degrees of color changes, pain and extensive gangrene. Buerger's original description stated that this disease occurred only in Hebrews and that tobacco, chiefly cigarette smoking, was a definite contributing factor. However it has since been demonstrated that no race is immune and that although most patients are cigarette smokers, this condition is seen in nonsmokers. The course of this disease is slow and for some time it may be manifested only by intermittent claudication and coldness of the extremities. Later color changes appear which vary from a deep rubor to marked cyanosis which is replaced by blanching when the extremity is elevated for a short time. Gangrene usually begins around the nail and involves all or part of one digit. Later it progresses until amputation is necessary unless adequate collateral circulation can be obtained.

The only means of producing adequate collateral circulation is to relieve the spasm of the vessels which are not occluded. This can be accomplished by severing the sympathetic fibers causing this vasoconstriction. It is obvious that these cases must be carefully selected so that there is an assurance that the collateral circulation will be adequate. Thromboangiitis obliterans occurs chiefly in men and care should be taken to avoid confusing early cases with Raynaud's disease because of a palpable vessel, as Brown and Allen have called attention to errors in diagnosis when pulsations were still present in distal arteries.

Arterial Sclerosis. Little can be hoped for in dilating the vessels of occlusive conditions in the later decades of life, but relief from intractable pain can be accomplished by alcohol injection of the sympathetic ganglia. The risk of injection is almost nil and is preferable to massive doses of narcotics in the hope of affording relief to these unfortunate suffers. It is also a distinct advantage to allay this intense distress so that the patient can be built up for amputation, if necessary, at a later date with a better assurance of healing and the elimination of the painful stump.

SELECTION OF CASES

The success of sympathectomy in the treatment of peripheral vascular disease depends entirely upon two factors, the proper selection of cases and the thorough interruption of all of the vasoconstrictor fibers. There are, at present, four methods of determining the suitable cases: (1) the "fever" test, (2) spinal anesthesia, (3) direct injection of nerve trunks and (4) direct injection of the sympathetic ganglia.

1. *The "fever" test* was devised by Adson and Brown in 1925 and consists of administering 25,000,000 to 75,000,000 dead bacilli in typhoid vaccine intravenously, according to the age of the patient, and estimating the rise in the surface temperature of the extremities in contrast to the rise in mouth temperature. This is an accurate means of determining the relative increase of blood flow in the vessels of the extremities. The objection to this method is that it causes a severe generalized reaction and is an indirect test because it only produces vasodilatation without giving information as to relief of pain.

2. *Spinal anesthesia* will produce vasodilatation but this method is limited because it gives no indication as to pain relief, as all sensations are absent, and is practical only for the lower extremities.

3. *Direct injection of the nerve trunks* often provokes technical difficulties and is incomplete as all sympathetic fibers are not interrupted.

4. *Direct injection of the sympathetic ganglia,* as advocated by White, produces a selective and discriminative result as both vasodilatation and pain relief are accomplished in as limited an area as desired.

In all of the foregoing diagnostic methods, it is essential to secure sufficient

vasodilatation or pain relief to warrant surgical procedures on sympathetic ganglia and rami.

Pain of Head, Face and Neck. Mixter and White postulated the theory that some of the pain fibers from the head and neck coursed through the inferior cervical and first thoracic sympathetic ganglia on their way to a central point of perception. This has been corroborated by Flothow who removed the stellate and second thoracic sympathetic ganglia in a case of facial neuralgia after section of the postganglionic root of the trigeminal nerve had failed to afford relief, and Abbott reported a similar case relieved by alcohol injection of the same ganglia. Dandy has removed the stellate and second thoracic ganglia for hemicrania and although the patients have not been observed over a very long period the results have been satisfactory to date. On the other hand, Frazier was disappointed in his cases in which he removed the cervical sympathetic chain by the anterior approach. However his results might have been more satisfactory if the posterior approach of Adson had been used. There is no doubt but that certain painful conditions of the head and neck can be relieved by cervicothoracic sympathectomy or alcohol injection when other methods fail.

Angina Pectoris. Many surgical procedures on the sympathetic nervous system have been devised for the relief of the pain of angina pectoris since Franck's original suggestion in 1899. It is universally agreed that any surgical procedure in this condition is only palliative but relief of pain is important not only from the standpoint of the patient but, as suggested by Wenckebach and Danielopolu, the pain in itself may be actually injurious to the heart.

The knowledge of the innervation of the heart is incomplete but it is generally conceded that the upper sympathetic ganglia are definitely involved so that ablation of these ganglia seems a logical procedure.

The most plausible theory of angina pectoris is that advocated by Danielopolu, which is based on the assumption of an inadequate coronary circulation whether there is a coronary sclerosis or an apparently normal heart. Thus the anginal attack arises from a disturbance of the balance between the work of the myocardium and the blood supply. The various operations consist of resection of different portions of the upper sympathetic ganglia and the most complete procedure is that of Jonesco, which is a resection of the entire cervical chain and first thoracic ganglia. Other operations consist of removal of the superior cervical ganglia, right, left or both, section of the trunk below the superior cervical ganglion and section of the superior cardiac nerve, removal of the superior and middle cervical ganglia, and removal of the stellate and second thoracic ganglia. No one type of operation has been universally successful. In 1924 Brunn and Mandl tried paravertebral nerve block with procaine with splendid results. Later Swetlow began the use of alcohol in these injections and since his original work many others have used this method with more constant results than following the operative treatment. This procedure seems most logical as it interrupts the visceral afferent pain fibers which pass through the rami communicantes and dorsal roots regardless of the route up to that point.

White injects the upper five thoracic roots with 5 c.c. of 1 per cent procaine followed by 5 c.c. of 85 per cent alcohol. This seems to be the most efficient method as a large percentage of the patients obtain immediate relief from pain which lasts for several months.

The only deleterious effects of the injection are disagreeable paresthesias in the segmental distribution but these last only a short time and are not as severe as the previous cardiac pain. There is no operative mortality in skilled hands. This seems a most satisfactory procedure because all patients suffering from anginal

pain are not good risks for as formidable an operation as sympathetic ganglionectomy.

Asthma. The reports of the surgical procedures on the thoracic sympathetic ganglia are so conflicting that, at present, no definite opinion can be formed in reference to the advisability of operation or alcohol injection for asthma.

Abdominal Pain. There is no problem more perplexing than that of a patient with a severe and often disabling abdominal pain which has failed to respond to the usual series of operations on the stomach, gall bladder, appendix or pelvic organs. There is a group of patients in whom the neurogenic factor is of paramount importance. In addition there is a group of patients suffering from inoperable neoplasms, which should be afforded relief from pain without resorting to massive and increasing doses of narcotics.

In recent years several means of interrupting pathways of pain have been devised with varying degrees of success. However it is now established that all of the visceral fibers in the sympathetic nervous system are connected with the posterior root ganglia of the spinal cord.

The earlier efforts to relieve intractable pain in the abdomen were confined to section of the posterior roots and cordotomy but too often these measures did not afford freedom from suffering. Later Von Gaza advocated section of the rami communicates and von Bogaert and Verbrugge achieved success in allaying various types of abdominal distress, including tabetic crisis, by this operation. Woodbridge has obtained satisfactory results by alcohol injections of the sympathetic ganglia and the results in the author's experience have been equally gratifying.

The distress of idiopathic dilatation of the colon or Hirschsprung's disease has been solved by lumbar sympathetic ganglionectomy as demonstrated by the reports of Wade and Royle, Judd and Adson, Rankin and Learmonth and Robertson. Many painful conditions in the pelvis which were unexplained by demonstrable pathology, or the lack of it, have been relieved by section of the hypogastric plexus or presacral nerve as indicated by the work of Leriche, Hovelaque, Fontaine and Herman. Learmonth's result in alleviating the distress of cord bladder and painful conditions of the lower urinary tract has solved a long-felt want and has been an outstanding contribution.

Although many advances have been made in relieving severe, and often unexplained, abdominal pain by section or injection of the sympathetic nervous system, much is to be learned by the possibilities, limitations and disadvantages of such procedures. It is obvious that extreme caution must be exercised in the selection of patients for such operations with due regard for the psychic element in each individual case.

OPERATIVE PROCEDURES

1. *Periarterial sympathectomy* consists of stripping the adventitia of the artery for a distance of 2 or 3 inches. This is facilitated by a preliminary injection of the adventitia with physiological saline solution.

2. *Cervicothoracic sympathetic ganglionectomy* is performed by making a midline incision from the tip of the spinous process of the fifth cervical vertebra to the fourth thoracic vertebra. The tendinous attachments of the trapezius, rhomboid and posterior serratus muscles are divided and the erector spinae and lower end of the splenius capitus muscles are exposed. A blunt dissection is made over the first thoracic vertebra and then a subperiosteal resection of 3 cm. of the rib and transverse process of the first thoracic vertebra is effected. The lung and pleura are gently dissected from the vertebra and retracted laterally. The sympathetic trunk is exposed and the second thoracic ganglion and rami are divided; then traction downward is made and the stellate ganglion, with its rami, is removed.

3. *Lumbar sympathetic ganglionectomy.* The patient is placed in the Trendelenburg

position. A midline abdominal incision is then made and the intestines pushed away. Adson mobilizes the sigmoid and lower portion of the descending colon by incising the parietal peritoneum laterally. Then the colon and ureter are retracted to the midline, also the aorta and vena cava are retracted mesially. The sympathetic trunk is removed from below the fourth lumbar ganglion up to, and including, the second lumbar ganglion and all the rami. On the right side, the incision in the peritoneum is made just lateral to the aorta and vena cava. The cecum, small intestine, ureter and the psoas muscles are then retracted laterally and the great vessels medially. Removal of the sympathetic trunk is similar to that on the left side.

An incision in the peritoneum immediately below the bifurcation of the aorta and carried upward above the aorta will facilitate exposure and diminish operating time.

Resection of the hypogastric plexus or presacral nerve is accomplished by incising the peritoneum below the bifurcation of the aorta and retracting the two sides of peritoneum laterally. The pelvic portion of the sympathetic chain is then removed.

SUMMARY

A brief review of the recent advances in the surgery of the sympathetic nervous system is presented in the hope that further interest will be aroused that will tend to a more complete knowledge of this mechanism, which undoubtedly holds the key to many unsolved problems. In such a limited survey of this field many valuable references have been omitted and it is with regret that all worthwhile contributions cannot be listed. However it is obvious that careful and deliberate selection of patient and operation will be of distinct advantage in many apparently hopeless cases, with a minimal mortality in skilled hands.

REFERENCES

1. Abbott, W. D. Sympathetic ganglionectomy in the treatment of vascular diseases. *Nebraska State M. J.*, 16: 104, 1931.
2. Abbott, W. D. Diagnostic and therapeutic injection of the sympathetic nervous system. *Nebraska State M. J.*, 17: 293, 1932.
3. Adson, A. W., and Brown, G. E. Treatment of Raynaud's disease by lumbar ramisection and ganglionectomy and perivascular neurectomy of the common iliac. *J. A. M. A.*, 84: 1908–1910, 1925.
4. Adson, A. W. Surgical relief of Raynaud's disease and other vascular disturbances by sympathetic ganglionectomy and perivascular neurectomy. *Ann. Clin. Med.*, 5: 161–167, 1926.
5. Adson, A. W., and Brown, G. E. Raynaud's disease of the upper extremities; successful treatment by resection of the sympathetic cervico-thoracic and second thoracic ganglions and the intervening trunk. *J. A. M. A.*, 92: 444–449, 1929.
6. Adson, A. W., and Brown, G. E. The treatment of Raynaud's disease by resection of the upper thoracic and lumbar sympathetic ganglia and trunks. *Surg. Gynec. Obst.*, 48: 577–603, 1929.
6a. Adson, A. W. Cervicothoracic ganglionectomy, etc. Am. J. Surg., n.s., 11:227, 1931.
7. Alexander. Quoted by Kuntz.
8. Archibald, E. Effect of sympathectomy for obscure pain. *Ann. Surg.*, 88: 499–509, 1928.
9. Brown, G. E. The skin capillaries in Raynaud's disease. *Arch. Int. Med.*, 35: 56–73, 1925.
10. Brown, G. E., and Adson, A. W. Calorimetric studies of the extremities following lumbar sympathetic ramisection and ganglionectomy. *Am. J. M. Sc.*, 170: 232–240, 1925.
11. Brown, G. E., and Allen, E. V. Thrombo-angitis obliterans; a clinical study of 200 cases. Treatment and prognosis. *Ann. Int. Med.*, 1: 550–557, 1928.
12. Brunn, F., and Mandl, F. Die paravertebrale Injektion zur bekamfung visceraler Schmerzen. *Wien. klin. Wchnschr.* 37: 511, 1924.
13. von Bogaert and Verbrugge, J. Pathogenesis and treatment of gastric crises of tabes by neuroramisectomy. *Surg. Gynec. Obst.*, 47: 543, 1928.
14. Dandy, W. E. Treatment of hemicrania (migraine) by removal of inferior cervical and first thoracic sympathetic ganglia. *Bull. Johns Hopkins Hosp.*, 48: 357–361, 1931.
15. Danielopolu, D. *Brit. M. J.*, 2: 553, 1924.
16. Danielopolu, D., and Hristide. *Compt. rend. Soc. de biol.*, 88: 271, 1923.
17. Flothow, P. G. Surgery of the sympathetic nervous system. A report of fourteen sympathetic ganglionectomies. Am. J. Surg., n.s. 10: 8–18, 1929.
18. Flothow, P. G. Diagnostic and therapeutic injection of the sympathetic nerves. Am. J. Surg., n.s., 14: 591–604, 1931.
19. Fontaine, R., and Herrman, L. G. Clinical and experimental basis for surgery of the pelvic sympathetic nerves in gynecology. *Surg. Gynec. Obst.*, 44: 133–163, 1932.
20. Franck. Quoted by Kuntz.

21. Frazier, C. H. A typical neuralgia. Unsuccessful attempts to relieve patients by operations on the cervical sympathetic system. *Arch. Neurol. & Psychiat.*, 19: 650, 1928.
22. von Gaza, W. Die Resektion der paravertebralen Nerven und die isolierte Durchschneidung des Ramus communicans. *Arch. f. klin. Chir.*, 133: 429, 1924.
23. Henderson, M. S., and Adson, A. W. Sympathetic ganglionectomy and trunk resection in arthritis; indications and results. *J. Bone & Joint Surg.*, 14: 47–56, 1932.
24. Henry, A. K. A new method of resecting the left cervico-thoracic ganglion of the sympathetic in angina pectoris. *Irish J. M. Sc.*, 5: 157–167, 1924.
25. Higier. Quoted by Kuntz.
26. Hovelacque, A. Anatomie des nerfs craniens et rachidiens et du systeme grand sympathetique. Paris, Doin, 1927.
27. Hunter, J. I. The influence of the sympathetic nervous system in the genesis of the rigidity of striated muscle in spastic paralysis. *Surg. Gynec. Obst.*, 39: 723–743, 1924.
28. Jaboulay. 1899. Quoted by Leriche.
29. Jonesco, T. Quoted by Kuntz.
30. Jonesco, T. Treatment chirurgical de l'angine de poitrine par la resection du sympatheque cervico-thorasique. *Presse méd.*, 1: 193–194, 1921.
31. Judd, E. S., and Adson, A. W. Lumbar sympathetic ganglionectomy and ramisectomy for congenital idiopathic dilatation of the colon. *Ann. Surg.*, 88: 479–498, 1928.
32. Kramer, J. G., and Todd, T. W. The distribution of nerves to arteries of arms with discussion of clinical value of results. *Anat. Rec.*, 8: 243–254, 1914.
33. Kuntz, A. Distribution of sympathetic rami to the brachial plexus. *Arch. Surg.*, 15: 871–877, 1927.
34. Kuntz, A. Autonomic Nervous System. Phila., Lea & Febiger, 1929.
35. Learmonth, J. R., and Braasch, W. F. Resection of the presacral nerve in the treatment of cord bladder. *Surg. Gynec. Obst.*, 41: 501–504, 1930.
36. Learmonth, J. R. Neurosurgery in the treatment of diseases of the bladder. *J. Urol.*, 25: 531, 1931.
37. Leriche, R., and Heitz, J. Resultats de la sympathectomie periarterielle dans la traitment des troubles nerveux post-traumatiques d'orde reflex. *Lyon chir.*, 14: 754–792, 1917.
38. Leriche, R., and Fontaine, R. Experimental and clinical contribution to the question of the innervation of the blood vessels. *Surg. Gynec. Obst.*, 47: 631–643, 1928.
39. Leriche, R., and Strecker, P. Reserches experimentales sue le nerf presacre. *Bull. Soc. anat. de Par.*, 53: 819, 1927.
40. Mixter, W. J., and White, J. C. Pain pathways in the sympathetic nervous system. *Arch. Neurol. & Psychiat.*, 25: 986, 1931.
41. Potts, L. W. The distribution of nerves to the arteries of the legs. *Anat. Anz.*, 47: 138–143, 1914–1915.
42. Rankin, F. W., and Learmonth, J. R. Section of the sympathetic nerves of the distal part of the colon and the rectum in the treatment of Hirschsprung's disease and certain types of constipation. *Ann. Surg.*, 92: 710–720, 1930.
43. Ransom, F. W. Anatomy of the sympathetic nervous system with reference to sympathectomy and ramisection. *J. A. M. A.*, 86: 1886–1890, 1926.
44. Raynaud, M. Local Asphyxia. London, New Sydenham Soc., 1888, pp. 1–150.
45. Robertson, D. E. Treatment of megalacolon by sympathectomy. *Ann. Surg.*, 94: 670, 1931.
46. Rowntree, L. G., and Adson, A. W. Bilateral lumbar and thoracic sympathetic ganglionectomy and ramisectomy for polyarthritis of the lower extremities. *J. A. M. A.*, 88: 694, 1927.
47. Royle, N. D. A new operative procedure in the treatment of spastic paralysis and its experimental basis. *Med. J. Australia*, 77: 1924.
48. Scrimger, F. A. C. On the possibility of relieving abdominal pain by section of the sympathetic rami communicanti. *Canadian M. A. J.*, 21: 184, 1929.
49. Stern, E. L. Alcohol injection of nerve roots for thrombo-angiitis obliterans. Am. J. Surg., n.s., 10: 107, 1930.
50. Swetlow, G. J. Paravertebral alcohol block in cardiac pain. *Am. Heart J.*, 1: 397, 1926.
51. Wade, R. B., and Royle, N. D. Operative treatment of Hirschsprung's disease; new method; with explanation of the technic and results. *Med. J. Australia*, 1–17, 1927.
52. Wenckebach, K. F. *Brit. M. J.*, 1: 809, 1924.
53. White, J. C. Diagnostic blocking of the sympathetic nerves to the extremities with procaine. *J. A. M. A.*, 94: 1382, 1930.
54. White, J. C. Angina pectoris; relief from pain by paravertebral alcohol block of upper dorsal sympathetic rami. In: Vegetative Nervous System. Coll. Papers Assn. for Research in Nerv. & Mental Disease. Balt., Williams & Wilkins, 1930, 9: 786–891.
55. Woodbridge. P. D. Therapeutic nerve block with procaine and alcohol. Am. J. Surg., n.s., 9: 278, 1930.

RECTAL ADMINISTRATION OF TRIBROMETHANOL

ITS USE ABROAD*

ERNST F. GOLDSCHMIDT AND SAMUEL C. HARVEY

NEW HAVEN, CONN.

THE chemical compound tribromethanol was produced by Willstaetter, the Nobel prize winner of 1915, and Duisberg[143] and has been in use as a general anesthetic on the Continent since 1927. However, reports regarding the value of the drug, its action, indications for its use, dosage, method of administration, etc. are at great variance (Anschuetz;[1,2,3] Boeters;[11] M. Borchardt;[13] Christ;[19] Domanig;[25] Heuss;[58] E. Muehsam;[88] R. Mühsam;[89] Sauerbruch[111]). It seemed desirable therefore to assemble the available data and thus gain an idea of the true situation (Goldschmidt and Harvey[48]). The procedure adopted was that of reviewing all of the literature abroad and of collecting information through direct inquiry by correspondence with the authors and heads of the respective institutions regarding their experiences and opinions on tribromethanol anesthesia.

The results of these studies indicate that failures and accidents may be justly ascribed to unskilled application of the anesthetic and that by proper indication, proper dosage and proper method of administration of tribromethanol these may be easily avoided and furthermore that the introduction of this drug as a basal anesthetic marks a new era in modern anesthesia.

PHYSICAL, CHEMICAL AND PHARMACOLOGICAL PROPERTIES

Tribromethanol (E 107, avertin, Byck 250, renarcol) is a white, crystalline substance, soluble in water at a temperature of 40° C. Chemically it is a tribromethyl alcohol, the result of an only vaguely described patented chemical process (S. Loewe;[80] Straub;[130] Herzberg;[57] Nestmann;[93] Welsch[139]). Formerly it has been given orally (Eckstein). At present, the intravenous (Kirschner,[64] Stich[129]) but mostly the rectal administrations are in use (Sebening[120]). According to the manufacturers' instructions, avertin fluid should be given in a 2½ per cent solution, freshly dissolved at body temperature in doses of 0.08 – 0.1 c.c. per kilogram of body weight. This dose should be lowered when the drug is given to debilitated, (Kleesattel;[65] Guleke[51]) cachectic, dehydrated or obese patients (Specht[125]) and raised for children and strong individuals between the ages of twenty and thirty-five years. In practice a variety of criteria are used for determining the dosage, such as age (B. Martin[81]), purpose of administration, whether basic or general anesthesia (B. Martin;[81,82] Sievers;[122] Kirschner;[64] Stich[129]) is desired. The action of the drugb yrectal administration, which is now the generally accepted method, depends on a number of factors (Roedelius[109]). One of these is the degree of absorption which varies according to the concentration of the solution used (Straub;[130] Kotzoglu;[68] Mörl[85]) and also on certain physical conditions such as the pressure under which the enema is introduced, position of the patient (Anschütz;[1] Goecke;[46] Haack;[52] Treplin[133]), etc. Another factor is the method of preoperative preparation of the patient. The combined use of narcotics and of admixture

* From the Department of Surgery, Yale University School of Medicine, New Haven, Connecticut. Submitted for publication August 1, 1932.

(Fränkel;[38] Riedel[108]) of various drugs in the tribromethanol enema modify its action (Grossmann[50]). It acts differently in man than in woman, the latter being more sensitive (Beck[7a]; Beck and Lendle;[7,60,73,74] Bolz and Borchers;[12] Cauchard and Monod;[18] Endoh;[32] Kaczander;[59] Kärber[60]). In animals the lethal dose is constant, 1.75 times higher than the full anesthetic dose (Anschütz[1]). The exact routes of the excretion of tribromethanol are not known (Wymer[146,147] and Fuss). Most of it is believed to be eliminated through the urine. According to Nordmann[95] the greater bulk is excreted during the first six hours but traces remain in the urine after two days. According to Sebening[120] and Straub[130] when 15 gr. of a 3 per cent solution of tribromethanol are administered, half of the drug is absorbed in ten minutes, three-fourths of it in twenty minutes. The rest is so slowly removed that 5 or 10 per cent is present in the fluid returned two hours after the instillation.

Of the pharmacological actions of tribromethanol which justify its preferred use to other anesthetics the following may be mentioned. The stage of excitement is absent, the patient gradually loses consciousness within two to fifteen minutes, surgical anesthesia is obtained after thirty minutes lasting for about two hours and is followed by sleep and analgesia for about four hours. There is complete amnesia of all events while under the action of the drug. Nausea and vomiting as after effects of the anesthesia are less severe or absent. A drop of the blood pressure without change in the pulse rate is observed during the instillation of the anesthetic. This, however, is no cause for alarm since it quickly returns to the level observed in normal sleep (Church;[20] Goldschmidt and Harvey;[48] Boas and Goldschmidt;[10] Kennedy;[62] Stuber;[131] Unger and May;[136,137] Wessely[140]).

Excitement after the anesthesia has been occasionally observed. According to Lexer,[75] Lobenhoffer[77] and Schulze[119] alcoholism may be responsible for it.

METHODS OF TRIBROMETHANOL INSTILLATION

In reviewing the literature and the answers to our inquiries, it was learned that there is a group of clinics which do not use tribromethanol at all (Table I), one which uses the drug for basal anesthesia and follows exactly the instructions of the manufacturer (Table II), and a third group which applies tribromethanol rectally but by individual methods (Table III). Here we are particularly concerned with the latter group.

1. *Nordmann's Method.*[95] Nordmann formerly used avertin in an enema which contained a demulcent of salep.* Later he found that this was not helpful and discontinued its use. Subsequently he added to the enema magnesium sulphate and calcium chloride but soon dispensed with all additions. Nordmann's followers use chloraethyl or solaesthin† as a supplementary anesthetic.

2. *Kreuter's Method.*[69] Kreuter administers tribromethanol in a 3 per cent solution in doses of 0.125 to 0.150 gm. per kilogram of body weight. No laxative is given the evening before the operation but a cleansing enema is given.

3. *Sievers's Method for Children.*[122] Sievers desires to obtain in each case full anesthesia and administers therefore .15 gm. of tribromethanol per kilogram of body weight in a 3 per cent solution. If after ten minutes the patient reacts to cold or pain, an additional dose of .025 gm. of the drug per kilogram of body weight is given. If, after this, complete anesthesia is not obtained, he either cancels the operation or orders a colonic irrigation and repeats the procedure after one hour. (Ebhardt.[27])

4. *B. Martin's Method.*[81] Martin aims to attain full anesthesia with tribromethanol by combining it with other drugs. The

* Demulcent of a dried tuber of a special kind of Orchis growing in Turkey.

† Solaesthin is a methylenchloride, related in its chemical structure to chloroform. It is non-explosive, can be dropped like ether, and is cheaper than chloraethyl.

essentials of this method are the addition of a 25 to 30 ccm. of a 20 per cent solution of magnesium sulphate to the 2½ per cent liquid avertin "stem-solution." He further adds 1 c.c. of a 3 per cent solution of narcophin.* This is omitted in children under fourteen years. The table used for the doses is given below.

Age	Avertin (Gm.)	Magnesium Sulfuricum (Ccm.)	Narcophin
1–14	0.17–0.18	30	
15–24	.15– .17	30	1.0
25–34	.14– .15	30	1.0
35–60	.13– .15	30	1.0
over 60	.13– .15 or less	30	1.0

According to B. Martin[81] the patient is asleep in two minutes, is unconscious after five minutes, and is in deep anesthesia after fifteen minutes. This stage lasts for seventy to one-hundred and ten minutes. He claims that the decrease in the blood pressure is less than by any of the other methods. Some are using Martin's method with the modification of not intending to induce full anesthesia and using therefore less tribromethanol (R. Mühsam,[89] Dax,[23] v. Redwitz[105]). The magnesium sulphate is given intramuscularly by v. Redwitz.[105]

5. *Method of the University of Leipzig* (Payr,[96] Plettner[100]). Laxative is not given the evening before the operation. The patient takes two tablets of adalin. On the morning of the operation again two tablets of adalin are given one hour before the operation, and .01 to .02 gram pantopon is injected hypodermically (none to children). Simultaneously with the instillation of the avertin, diluted in salep, one ampule of cardiazol† is given subcutaneously. If the patient is not in deep sleep after ten minutes a supplementary enema of .025 gm. of avertin per kilogram of body weight is given. The operation is followed by a cleansing enema with camillosan.‡

* Narkotin-morphin-mekonat is a double salt of morphin and narkotin. It is a quite ineffective alkaloid compound with meconic acid.

† Lobelin 0.003 gm. and ephetonin .005 gm.

‡ An infusion of Camomilla Romana or Anthemis nobilis.

TECHNICAL DETAILS OF TRIBROMETHANOL ANESTHESIA AS FOLLOWED IN THE EUROPEAN CLINICS

(a) *Preparation of the lower colon on the evening before the operation* is regarded necessary. Many emphasize that they would rather have too little than too much done. Nordmann,[95] and B. Martin[81] claim to have satisfactory results without any previous preparation of the colon.*

(b) *The administration of a hypnotic the evening before operation* is recommended by the manufacturer[5] who suggests phanodorn, luminal and veronal. Other drugs used are medinal, noctal, veronacetin and veramon (Poppert[101] and Schmieden[116]), dilaudid (Lobenhoffer[77]); adalin (Momburg,[86] Lobenhoffer,[77] R. Mühsam,[89] Payr[96]) narcophin (Seefisch[121]). Opinions differ considerably regarding the necessity and use of hypnotics. Some emphasize their use (Sievers[122]) while others (Glaesmer;[43] B. Martin;[81] v. Eiselsberg;[29] Starlinger,[127] Lexer;[75] Schulze;[119] H. Schmidt;[115] Clairmont[21]) are against it.

(c) *An analgesic before induction of the anesthesia* is administered by many. The manufacturer suggests morphia. Others use narcophin (Seefisch[121]), pantopon (Anschütz;[1] Goetze;[47] Friedrich;[39] Poppert;[101] v. Brandis and Killian;[14] Glahn;[44] Pels-Leusden;[97] Wiedhopf[142]), laudanon (Baum;[6] Anschütz[1]), dilaudid (Nordmann;[95] Wiedhopf[142]), veronal (Clairmont[21]), and narcophin (Stemmler;[128] Seefisch;[121] B. Martin[81]).

(d) *Supplementation of tribromethanol with inhalation anesthetics* (Wuelfing[145]). The following drugs used are given in order of frequency:

1. Ether. It is generally agreed that the quantity of ether necessary is a fraction of that without tribromethanol.

2. Nitrous oxide—Oxygen (Domanig;[25] Flörcken;[36] Mues[90]).

3. Chlorethyl.

* Psychiatrists (Sioli and Neustaudt;[123] Blume;[9] Enke;[33] Westphal;[141] Gallinek;[41] Richet and Joly[107]) used tribromethanol rectally with good results without first preparing the colon.

4. Local anesthesia: novocaine-suprarenin 0.5 per cent solution is used by Lobenhoffer;[77] Sievers;[122] v. Gaza;[42] Mintz.[84] Braun[15] recommends this combination in strumectomies and cholecystectomies only. Läwen,[71] B. Martin[81] and Anschütz[1] are against the use of local anesthesia, fearing the blood pressure change and disturbances in the general condition of the patient.

5. Solaesthin (Nordmann[95] and Mintz[84]).

6. Narcylen (Lobenhoffer[77]).

DISTURBANCES DURING AND AFTER THE AVERTIN ANESTHESIA AND ANTIDOTES FOR THEM

Respiratory difficulties in the beginning, during and after operation have been observed, even when small dosages of the drug have been administered (Pfister[99]). The following antidotes are in use:

1. CO_2—inhalation (Schmieden, Sevening, Pels-Leusden, Anschütz, Heuss, Braun, Martin, Lexer, v. Redwitz, Roedelius, Sudeck, H. Schmidt, Unger, Mintz).

2. Lobelin (Momburg, Baum, Pels-Leusden, Druegg, Schloffer,[114] Moerl, B. Martin, Kreuter).

3. Artificial respiration (v. Eicken, Elsbach).

4. Oxygen (v. Eicken, Elsbach); oxygen alternating with CO_2 (Heile, Rodelius, Sudeck, H. Schmidt).

5. Cardiazol (Lexer, Schulze).

6. Cardiazol-lobelin given subcutaneously the same time as the avertin is instilled (Payer).

7. Camphor and caffeine (Braun, Elsbach, v. Eicken).

8. Ephedrin (B. Martin, Momburg, Grossmann, Domanig).

9. Ephetonin (Heuss, Schloffer, Moerl, Lexer, Schulze, Payr, Plettner, Atanasof, Stahnke) given subcutaneously at the time of avertin instillation.

10. Suprarenin (B. Martin).

11. Venesection (Schmieden, Sebening) followed

(a) by glucose infusion (Schmieden, Sebening, Pels-Leusden, Lexer, Schulze) or

(b) Ringer solution infusion (Schmieden, Sebening, Pels-Leusden).

12. Glucose the day before operation (Denke, Domanig).

13. Cleansing enema (Momburg and Payr).

14. Thyroxin (Pribram, Lexer, Schulze). This according to von Gaza[42] does not interrupt the anesthesia but shortens the after-sleep; Nell[91] and Sebening[92] reported it to be effective only if given for a few days before the operation.

15. Cocaine (2 c.c. of a 1 per cent solution plus 2 c.c. 20 per cent caffeine) is described lately by B. Martin and Kotzoglu,[82] and Seefisch.[121]

16. Coramine. Its action, supposed to be identical with camphor, stimulates respiration and the heart action and is antagonistic to morphine (Uhlmann[135]). Recently Killian,[63] Mörl[85] and Fischmann;[35] Killian and Uhlmann[63a] reported that it was effectual in interrupting avertin narcosis (also: Baum, M. Borchardt, Denk, v. Gaza, Nordmann, H. Schmidt, Unger, Specht).

17. Extract of the thymus (Domanig[25]).

MORTALITY

It seems impossible to elicit the exact number of avertin anesthesias performed and so reliable figures on fatal outcome are unobtainable. Only the manufacturers know how many tribromethanol anesthesias are performed. Their estimate is 250,000. Our estimate from the figures reported is about 40,000 (July, 1931). In this figure, however, the clinics for women are not included (Butzengeiger;[17] Loeser;[78] Stahnke;[126] Beck[7a]). E. Martin[83] performed 4500 anesthesias during labor. The papers about fatal cases (v. Scanzoni;[112] Schrödl;[118] Pribram;[102] Hahn[54]) where death was presumably caused by tribromethanol, have been again and again analyzed and criticized (Nordmann;[95] Glaesmer;[43] Hahn;[54] Kotzoglu;[68] Behrend;[8] Anschütz;[1] Schulze[119]). It is therefore rather difficult to determine what percentage of the deaths have really been caused by the drug.

Anschütz investigated the mortality of 79,750 cases (April, 1932) and came to the conclusion that in only 6 of these was the connection between the avertin anesthesia and the exitus evident.

Indeed, we asked for statements about death cases. We obtained *one* such report (Bsteh[16]) in which undoubtedly avertin was the cause of death. The explanation for this astonishing drop in fatal accidents seems to be better technique and better judgment in the selection of cases.

REPEATED USE OF TRIBROMETHANOL

Repeated use of tribromethanol was reported by Wolf;[144] Lindemann;[76] Knop;[66] Goebel;[45] and Lehrnbecher.[72] Repeated doses of tribromethanol were given in cases of tetanus (Lobenhoffer;[77] Momburg and Rotthaus;[87] Denk;[24] Kaspar;[61] G. Loewe,[79] Schaefer;[113] Uebelhör;[134] Wiedhopf[142]). In cases of subsequent operations on the same individual (Poppert;[101] Lexer;[75] Schulze[119]), in cases of eclampsia (Ruge[110]) and in chorea (Westphal;[141] Enke[33]).

SUMMARY

1. Reports concerning the latest experiences with tribromethanol in the leading clinics of Germany, Austria, Switzerland and other countries abroad are analyzed.

2. Technique in the use of tribromethanol has been standardized, its use is increasing.

3. The rectal administration of tribromethanol is valuable in selected cases; its introduction as a basal anesthetic marks a new era in modern anesthesia.

Table I

CLINICS NOT USING TRIBROMETHANOL

1. Chir. Klinik d. Universität Bern: de Quervain, F.[103]* "Margin of anesthesia too small; mortality too high; uncontrollable; too toxic."
2. Chir. Universitätsklinik Freiburg, i. B.: 300 beds,: v. Brandis, H. I.[14] Killian, H.[14,63]† "Preferring other anesthesias."
3. Chir. Abt. a. St. Krankenhaus r.d.I., Munich, 900 bed hosp.: Grasmann, M.;[49]* "Preferring other anesthesias."
4. Krankenhaus Wieden, Vienna,: Schnitzler, J.,[117]* "Undesirable."

* Head of the Clinic.

† But: see Killian's report on coramine.[63,63a]

Table II

CLINICS USING TRIBROMETHANOL RECTALLY AS A BASAL ANESTHETIC FOLLOWING MANUFACTURERS' INSTRUCTIONS

1. Buergerspital Basel, Chir. Universitätsklinik: Henschen, G.[56]* Christ, A.[19]
2. St. Krankenhaus. Friedrichshain, Berlin: 1201 bed hosp.: Braun W.[15]*
3. St. Hildegard-Krankenhaus, Berlin-Charlottenburg: 138 bed hosp.: Pribram, B. O.[102]*
4. Chir. Abt. a. Krankenhaus Moabit u.d. III. Chir. Universitätsklinik, Berlin: 1025 bed hosp.: Borchardt, M.[13]*
5. Chir. Universitätsklinik der Charité, Berlin, 256 beds: Sauerbruch, F.;[111]* Nissen, R.[94]
6. Lazarus-Kranken-u. Diakonissenhaus, Berlin N., 200 bed hosp.: Seefisch, G.[121]*
7. St. Rudolph-Virchow-Krankenhaus, II. Chir. Abtl; Berlin: 259 bed hosp.: Unger, E.;[137]* May, H.[137]
8. St. Krankenhaus Bielefeld: 453 bed hosp.: Momburg, F.;[86,87]* Rotthaus, E.[87]
9. Chir. Universitätsklinik Breslau: 163 beds: Küttner, H.[70]*
10. Chir. Universitätsklinik Erlangen: 205 beds: Goetze, O.;[47]* Friedrich, H.[39]
11. Diakonissenanstalt Flensburg: 220 bed hosp.: Baum, E. W.[6]*
12. Chir. Klinik d. St. Marienkrankenhaus, Frankfurt a.m.: 310 bed hosp.: Flörcken, H.;[36,37]* Mues, O.[90]
13. Chir. Universitätsklinik im St. Krankenhaus Sachsenhausen, Frankfurt/Main: 323 beds: Schmieden, V.;[116] Sebening, W.[120]
14. Chir. Universitätsklinik Giessen: 239 beds: Poppert, P.;[101]* Glahn, A.[44]
15. Karolus Krankenhaus Goerlitz: 45 beds: Boetesr, O.[11]*
16. Chir. Universitätsklinik Graz: Denk, W.;[24]* Domanig, E.;[25] Uebelhör, R.[134]
17. Chir. Universitätsklinik Greifswald: 120 beds: Pelz-Leusden, F.[97]*
18. Universitätskliniken Halle (Chir. Abtl. u. Nervenklinik): 367 beds: Voelcker, F.;[138]* Gallineck, A.[41]
19. Akademisches Krankenhaus, Chir. Klinik, Heidelberg: 276 beds: Enderlen, E.[31]*
20. Chir. Universitätsklinik Innsbruck: Ranzi, E.[104]*
21. St. Krankenhaus, Chir. Abt., Karlsruhe i.B.: 691 bed hosp.: Haas, W.[53]
22. Chir. Universitätsklinik Kiel: 249 beds: Anschütz, W.;[1,2,3]* Specht, K.;[125] Tiemann, F.[3]
23. Chir. Universitätsklinik Lindenburg, Koeln: 278 beds: Drügg, W.[26]
24. Chir. Universitätsklinik u. Poliklinik Koenigsberg Pr.: 203 beds: Läwen, A.[71]*
25. Chir. Klinik d. Universität Marburg/Lahn: 132 beds: Wiedhopf, O.[142]
26. Staatl. preuss. chirurgische Universitätsklinik Muenster i.W.: 160 beds: Coenen, H.;[22]* Nestmann, F.[93]
27. Jewish Hospital, Riga: Mintz, M.[84]
28. Chir. Universitätsklinik Rostock: 296 beds: v. Gaza, W.[42]*
29. I. Chirurgische Universitätsklinik des Prof. A. Eiselsberg, Vienna: v. Eiselsberg, A.;[29]* Starlinger, F.[127]

* Head of the clinic.

TABLE II (*Continued*)

30. Diakonissenhaus Paulinenstift, Wiesbaden: 233 bed hosp.: Heile, B.[55]*
31. Diakonissenhaus Witten: 330 bed hosp.: Heuss, H.[58]*
32. Chir. Universitätsklinik Würzburg; 980 bed hosp.: Koenig, F.[67]*

* Head of the clinic.

TABLE III

CLINICS USING TRIBROMETHANOL RECTALLY FOLLOWING THEIR OWN METHODS

I. Nordmann's method

1. Chir. Abt. d. Auguste-Viktoria-Krankenhauses, Berlin-Schoeneberg: 760 bed hosp.: Nordmann, O.[95]*
2. Chir. Klinik d. St. Krankenanstalt Bremen: 1450 bed hosp.: Smidt, H.[124]*

II. Kreuter's method

1. Universitaets-Hals-Nasen- u. Ohrenklinik und Poliklinik Charité, Berlin: 100 beds: v. Eicken, C.;[28]* Elsbach, K.[30]
2. Kaiserin Auguste-Viktoria-Krankenhaus, Berlin-Licherfelde: 92 bed. hosp.: Herzberg, M.[57]
3. St. Krankenhaus, Chir. Abtl. Frankfurt/Oder: 350 bed hosp.: Ruge, E.[110]*
4. St. Krankenhaus, Koeln-Muelheim: 263 bed hosp.: Haack, E.[52]
5. Allgemeines Staedtisches Krankenhaus, Nuernberg: 1605 bed hosp.: Kreuter, E.[69]*
6. Deutsche Chir. Universitätsklinik, Prague: Schloffer, H.;[114]* Mörl, F.[85]

TABLE III (*Continued*)

III. Sievers's method

1. Universitäts-Kinderklinik und Poliklinik zu Leipzig, Chir. Abtl.: 350 bed hosp.: Sievers, R.[122]*

IV. B. Martin's method

1. Allgemeines Krankenhaus zu Bamberg: 1300 bed hosp.: Lobenhoffer, W.[77]*
2. Chir. Universitätsklinik Berlin: 223 beds: Martin, B.[81,82]
3. Chir. Abtl. des Stadtkrankenhauses Friedrichsstadt, Dresden A. 24: 613 bed hosp.: Fromme, A.[40]*
4. Universitätsklinik Jena, Chir. Abtl.: 450 beds: Guleke, N.[51]*
5. Chir. Klinik Muenchen: 1819 bed-hosp.: Lexer, E.,[75]* Schulze, W.[119]
6. Kantonsspital Zuerich, Chir. Klinik: Clairmont, P.[21]*

V. Variations of B. Martin's method

1. Rudolph-Virchow-Krankenhaus, Chir. Abtl.: 2591 bed hosp.: Mühsam, R.[89]*
2. Chir. Universitätsklinik Bonn: 162 beds: v. Redwitz, E.[105]*
3. Chir. Universitätsklinik Hamburg-Eppendorf: 2638 bed hosp.: Sudeck, P.;[132]* Roedelius, E.;[109] Schmidt, H.[115]
4. Chir. Abtl. a. Krankenhaus Schwabing, Muenchen: 1910 bed hosp.: Dax, R.[23]*

VI. Payr's method

1. Chir. Klinik der Universität Leipzig, im St. Krankenhaus zu St. Jakob: 465 beds: Payr, E.;[96]* Plettner, F.[100]

* Head of the clinic.

BIBLIOGRAPHY

1. ANSCHÜTZ, W. Zur Eröffnung einer allgemeinen Aussprache über die Avertinnarkose in Zentralblatt für Chirurgie. *Zentralbl. f. Chir.*, 55: 2371–2377, 1928.
   Zur Aussprache über die Avertinnarkose. *Zentralbl. f. Chir.*, 56: 734–743, 1929.
   Die Atemstörungen bei Avertinnarkose, ihre Vermeidung und ihre Bekämpfung. *Zentralbl. f. Chir.*, 57: 1010–1017, 1930.
   Die Darmnarkose mit Avertin. Soc. internat. de chirurg. IX congrès Madrid 15–18 mars 1932. Imprimerie med. et scient. Bruxelles, 1932.
   Personal communications Jan. 17, Sept. 5, 1931, July 1, 1932.
2. ANSCHÜTZ, W., and SPECHT, K. Beiträge zur Avertin-Narkose. *Therap. d. Gegenw.*, n. F. 32: 20–24; 53–56, 1930.
3. ANSCHÜTZ, W., SPECHT, K., and TIEMANN, F. Die Avertinnarkose in der Chirurgie. Berlin, Springer, 1930.
4. ATANASOF. Ueber die Anwendung des Ephetonin-Merck bei der rektalen Avertinnarkose. *Med. Klin.*, No. 21, 827, 1929.
5. AVERTIN. Ed. 2. J. G. Farben Industrie, 1929.
6. BAUM, E. W. Aussprache zu: Kirschner; Erfahrungen mit der intravenösen Avertin-Betäubung. *Arch. f. klin. Chir.*, 162: 51–52, 1930.
   Rektale Rauschnarkose mit Avertin. *Zentralbl. f.* 1848–1849, 1930.
   Steuerung der rektalen Avertinnarkose. *Zentralbl. f. Chir.*, 57: 450–451, 1930.
   Personal communications Jan. 12, Feb. 3, May 18, Aug. 24, 1931.
7. BECK, A., and LENDLE, L. Quantitative Untersuchungen ueber das Avertinentgiftungsvermoegen, *Arch. f. exper. Path. u. Pharmakol*, 164: 188, 1932.
   Ueber die Dauer der Avertinnarkose bei verschiedenen Tierarten. *Arch. f. exper. Path. u. Pharmakol.*, 164: 201, 1932.

7a. BECK, W. Wert und Eignung der Avertinmastdarmnarkose für die Gynäkologie. *Ztschr. f. Geburtsh.*, 101: 189, 1931.

8. BEHREND, C. M. Bemerkungen zum Aufsatz von Prof. Dr. O. Nordmann: Die bisher veröffentlichten Todesfälle nach Avertin. *Chirurg*, 2: 72–73, 1930.
9. BLUME, G. Ueber Avertin in der Psychiatrie. *Deutsche med. Wchnschr.*, 53: 1307–1309, 1927.
   Zur Frage der Avertinnarkose in der Psychiatrie. *Deutsche med. Wchnschr.*, 55: 61–62, 1929.
10. BOAS, E. P., and GOLDSCHMIDT, E. F. The Normal Human Heart Rate. Springfield, Ill., Thomas, 1932.
11. BOETERS, O.—Avertinnarkose. *Klin. Wchnschr.*, 7: 1302, 1928.
    Personal communications Feb. 2, Mar. 18, May 18, and Sept. 27, 1931.

12. Bolz, W., and Borchers, A. Versuche mit Avertin als Narkoticum beim Pferde. *Arch. f. wissensch. u. prakt. Tierheilk.*, 64: 18; 1931.
13. Borchardt, M. Zur Rektalnarkose mit Avertin, E 107. *Deutsche med. Wchnschr.*, 53: 909–911, 1927.
Personal communications Mar. 17, May 17, July 6, and Sept. 8, 1931.
14. v. Brandis, H. J., and Killian, H. Pantoponmagnesiumsulfat, Skopolamin, Avertin. *Zentralbl. f. Chir.*, 56: 1350–1354, 1929.
15. Braun, W. Personal communications Mar. 26 and July 4, 1931.
16. Bsteh, O., Links, R., and Wasserburger, K. Avertinnarkose und Grundumsatz. *Klin. Wchnschr.*, 10: 639–641, 1931.
17. Butzengeiger, O. Klinische Erfahrungen mit Avertin (E 107). *Deutsche med. Wchnschr.*, 53: 712–713, 1927.
Zur Avertinaussprache. *Zentralbl. f. Chir.*, 56: 204–208, 1929.
Personal communication Sept. 14, 1931.
18. Cauchard, A.-B., and Monod, R. Recherches physiologiques sur l'anesthésie par le tribromoéthanol. *Compt. rend. Soc. de biol.*, 108: 1113–1115, Jan. 8, 1932.
19. Christ, A. Ueber Rektalnarkose mit Avertin. *Schweiz. med. Wchnschr.*, n. s. 10: 723–725, 1929.
Personal communication Aug. 24, 1931.
20. Church, J. S. Report on avertin anaesthesia. *New Zealand M. J.*, 29: 153–156, 1920.
21. Clairmont, P. Personal communications Jan. 31, May 19 and 27, Oct. 6, 1931.
22. Coenen, H. Personal communications Jan. 5 and May 18, 1931.
23. Dax, R. Personal communications Jan. 20 and May 20, 1931.
24. Denk, W. (Graz). Personal communications Jan. 20, Mar. 14, May 19, Sept. 2, 1931.
25. Domanig, E. Vorschlag einer individuellen Dosierung der Avertinbasisnarkose. *Zentralbl. f. Chir.*, 56: 2191–2198, 1929.
Die Avertinbasis-Lachgasnarkose. *Chirurg*, 2: 750–755, 1930.
Ueber moderne Narkosemethoden. *Wien. klin. Wchnschr.*, 43: 1026–1031, 1930.
Die Avertinanwendung und die Bekaempfung ihrer Gefahren. *Wien. klin. Wchnschr.*, 2: 1129, 1931.
26. Drügg, W. Personal communications Mar. 10, May 19, Aug. 24, 1931.
27. Ebhardt, K. Erfahrungen mit der Avertinbasisnarkose, insbesondere auch in der Kinderchirurgie und beim Krankentransport. *Zentralbl. f. Chir.*, 57: 452–455, 1930.
28. v. Eicken, C. Personal communications Jan. 9, Feb. 7, May 20, 1931.
29. Eiselsberg, v. A (Vienna). Personal communications Jan. 16, Feb. 18, May 20, Aug. 31, 1931.
30. Elsbach, K. Rektalnarkose mit Avertinamylenhydratlösung. *Ztschr. f. Hals-, Nasen-u. Obrenb.*, 23: 290–295, 1929.
31. Enderlen, E. Ausschauung über die Avertinnarkose. *Deutsche med. Wchnschr.*, 53: 2065, 1927.
Personal communications Jan. 2, Feb. 3, May 17, 1931.
32. Endoh. Ueber das Verhalten des Tribromäthylalkohols im Tierkörper. *Biochem. Ztschr.*, 152: 276–280, 1924.
33. Enke, W. Das Problem der Dauerschlafbehandlung in der Psychiatrie. *München. med. Wchnschr.*, 76: 1961–1962, 1929.
34. Enke, W., and Westphal, K. Avertin als Hypnoticum und Dauerschlafmittel in der Psychiatrie. *Ztschr. f. d. ges. Neurol. u. Psychiat.*, 114: 616–629, 1928.
35. Fischmann, J. Coramin als Weckmittel bei Avertinnarkosen. *Deutsche med. Wchnschr.*, 58: 212–214, Feb. 5, 1932.
36. Flörcken, H. Beeinflussung des Avertinschlafs durch Kohlensäureinhalation. *Zentralbl. f. Chir.*, 55: 1925–1926, 1928.
Ueber die kombinierte Avertin-Lachgasnarkose. *Med. Klin.*, 26: 1854–1855, 1930.
Personal communications Jan. 4, May 18, Aug. 25, 1931.
37. Flörcken, H., and Mues, O. Ueber die Lachgasnarkose und besonders ihre Kombination mit der rektalen Avertinnarkose. *Deutsche Ztschr. f. Chir.*, 227: 462–467, 1930.
38. Fränkel, S. Die Arzneimittelsynthese. Ed. 6, Berlin, Springer, 1927.
39. Friedrich, H. Personal communications Jan. 13, Mar. 11, May 21, 1931.
40. Fromme, A. Personal communications Jan. 23, May 19, 1931.
41. Gallinek, A. Die Avertinnarkose in der Neurologie und Psychiatrie. *Monatschr. f. Psychiat. u. Neurol.*, 73: 109–115, 1929.
Personal communication Aug. 27, 1931.
42. v. Gaza, W. Personal communications Mar. 6, June 1, Sept. 16, 1931.
43. Glaesmer, E. Analyse der Avertinmortalität. *München. med. Wchnschr.*, 76: 2089–2091, 1929.
Analyse der Avertinmortalität. *München. med. Wchnschr.*, 77: 541–542, 1930.
Personal communications Mar. 14, Sept. 19, 1931.
44. Glahn, A. Personal communications Feb. 3, May 26, Sept. 5, 1931.
45. Goebel. Tetanusbehandlung mit Avertin. *Zentralbl. f. Chir.*, 55: 2524, 1928.
46. Goecke, P. Die Avertinrektaltropfnarkose. *Zentralbl. f. Chir.*, 55: 5–6, 1928.
47. Goetze. Aussprache zu: König: Tod nach Avertinnarkose. *Zentralbl. f. Chir.*, 56: 1895, 1929.
48. Goldschmidt, E. F., and Harvey, S. C. Avertinnarkosen, Referat ueber d. Nordamerikanische Literatur u. eigene Erfahrungen (mit vergleichenden Herzfrequenzstudien). *Klin. Wchnschr.*, 11: 23; 70, 1932.
49. Grasmann, M. Personal communications Jan. 25, May 23, 1931.
50. Grossmann, H. Avertinlösung in Amylenhydrat. *Zentralbl. f. Gynäk.*, 53: 780–783, 1929.
Personal communication Oct. 9, 1931.
51. Guleke, N. Avertinnarkose bei Phrenikusexairese. *Zentralbl. f. Chir.*, No. 1, 2, 1929.
Personal communications Jan. 19, May 20, 1931.
52. Haack, E. Zur Avertinrektaltropfnarkose. *Zentralbl. f. Gynäk.*, 52: 881–882, 1928.
Personal communications Jan. 31, Mar. 30, May 22, 1931.

53. Haas, W. Personal communications Mar. 4, May 22, 1931.
54. Hahn, K. Beitrag zur Frage der Avertintodesfälle. Inaug. Dissert. Breslau, 1930.
55. Heile, B. Personal communications Feb. 11, May 18, Aug. 26, 1931.
56. Henschen, G., and Christ, A. Personal communications Mar. 10, May 15, 1931.
57. Herzberg, M. Pharmakologische Versuche mit Avertin. *Deutsche med. Wchnschr.*, 54: 1044–1045, 1928.
Personal communications Jan. 26, May 27, Sept. 1, 1931.
58. Heuss, H. Erfahrungen mit der Avertinrektalnarkose. *Ztschr. f. ärztl. Fortbild.*, 25: 422–424, 1928.
Personal communications Jan. 15, Mar. 15, May 26, 1931.
59. Kaczander, P. Zur Frage der Lebergiftigkeit des Avertin. *Klin. Wchnschr.*, 9: 495–497, 1930.
60. Kärber, G., and Lendle, L. Untersuchungen über kombinierte Narkosen. iv. Mitt. Die Narkosebreite der kombinierten Avertin-Aethernarkose im Tierversuch. *Arch. f. exper. Path. u. Pharmakol.*, 142: 1–16, 1929.
Untersuchungen über kombinierte Narkosen. Ueber Konzentrationswirkungskurve des Avertins am Atemzentrum des Kaninchens und über die kombinierte Avertin-Morphinwirkung auf die Atmung. *Arch. f. exper. Path. u. Pharmakol.*, 143: 88–107, 1929.
61. Kaspar, M. Tierversuche zur Behandlung des Tetanus mit Avertin. *Bruns' Beitr. z. klin. Chir.*, 145: 313–321, 1928.
62. Kennedy, W. P. Preliminary note on blood pressure during avertin anaesthesia. *Edinb. M. J.*, 37: 142–152, 1930.
The blood pressure in avertin anaesthesia. *Brit. J. Anaesth.*, 8: 52–63, 1931.
63. Killian, H. Avertin und Phrenikotomie. *Zentralbl. f. Chir.*, 55: 2626–2630, 1928.
Zu den Meinungsverschiedenheiten über die Avertinrektalnarkose. *Chirurg*, 2: 567–571, 1930.
Ueber die Unterbrechungsmöglichkeiten der Avertinnarkose. *Zentralbl. f. Chir.*, 58: 1353–1354, 1931.
Personal communications Jan. 29, June 18, July 11, 1931.
Ueber die Unterbrechungsmöglichkeiten der Avertinnarkose. *Klin. Wchnschr.*, 10: 1446, 1931.
63*a*. Killian, H., and Uhlmann, F. Ueber die Reduktion der Avertinnarkose durch Coramin. *Naunyn-Schmiedebergs Arch.*, 163: 122, 1931.
64. Kirschner, M. Zur Theorie und Praxis der Mastdarmbetäubung mit E 107. *München. med. Wchnschr.*, 74: 917–918, 1927.
Eine psycheschonende und steuerbare Form der Allgemeinbetäubung. *Chirurg*, 1: 673–682, 1929.
Erfahrungen mit der intravenösen Avertinnarkose. *Arch. f. klin. Chir.*, 162: 361–387, 1930.
Personal communication Sept. 1, 1931.
65. Kleesattel, H. Avertinbetaeubung bei Lungentuberkulose, *Deutsche med. Wchnschr.*, No. 48, 1930.
66. Knop, F. Avertin zur Behandlung des Tetanus. *München. med. Wchnschr.*, 77: 184, 1930.
67. Koenig, F. Personal communications Apr. 4, May 19, 1931.
68. Kotzoglu, P. Ueber die Todesfälle in Avertinnarkose. *Zentralbl. f. Chir.*, 56: 2206–2212, 1929.
Warum wird die 2½%ige Avertinlösung besser vertragen als die 3%ige? *Zentrabl. f. Chir.*, 56: 717–718, 1929.
69. Kreuter, E. Zur Rektalnarkose. *Arch. f. klin. Chir.*, 148: 107, 1927.
650 Rektalnarkosen mit Avertin (E 107). *Zentralbl. f. Chir.*, 54: 3074–3076, 1927.
Ueber die Avertinnarkose. *Deutsche med. Wchnschr.*, 54: 562, 1928.
Personal communications Jan. 2, May 26, Aug. 26, 1931.
70. Küttner, H. Personal communications Jan. 12, May 21, Aug. 31, 1931.
71. Läwen, A. Avertin zur Behandlung des Tetanus. *Zentralbl. f. Chir.*, 54: 2370–2377, 1927.
Weitere Erfahrungen über die symptomatische Behandlung des Tetanus mit Avertin. *Zentralbl. f. Chir.*, 55: 194–201, 1928.
Personal communications Jan. 2, Mar. 2, May 18, Sept. 4, 1931.
72. Lehrnbecher. Intrazisternale Serumbehandlung bei Tetanus. *Zentralbl. f. Chir.*, 56: 905–907, 1929.
73. Lendle, L. Untersuchungen über den verschiedenen Angriffspunkt einiger Narkotika im Zentralnervensystem. *Arch. f. exper. Path. u. Pharmakol.*, 143: 108–116, 1929.
Verhältnis von Dosis zur Wirkung bei narkotischen Substanzen aus verschiedenen Gruppen (nach Untersuchungen am Atemzentrum des Kaninchens). *Arch. f. exper. Path. u. Pharmakol.*, 144: 76–82, 1929.
Ueber die Narkosenbreite des Avertin und der kombinierten Avertinbasisnarkose. *Deutsche med. Wchnschr.*, 56: 779–780, 1930.
Ueber die Bedingungen der "Basisnarkose" bei kombinierten Narkoseverfahren. *Klin. Wchnschr.*, 9: 1609–1615, 1930.
Personal communications Jan. 30, Mar. 3, May 21, Aug. 26, 1931.
74. Lendle, E., and Tunger, H. Bedeutung der Narkosedauer und Narkosebreite für die Auswahl der Basisnarkotica unter besonderer Berücksichtigung der Verabreichungsart. *Klin. Wchnschr.*, 9: 1293–1296, 1930.
75. Lexer, E., and Schulze, W. Personal communications Jan. 21, June 5, 1931.
76. Lindemann, K. Zur Anwendung des Avertin beim Wundstarrkrampf. *Zentralbl. f. Chir.*, 56: 1282–1284, 1929.
77. Lobenhoffer, W. Ueber Narkosen mit E 107. *München. med. Wchnschr.*, 74: 849–850, 1927.
Personal communications Jan. 25, Feb. 18, May 20, Sept. 2, 1931.
78. Loeser, A. Rektalnarkose mit E 107. *Med. Klin.*, 23: 531–532, 1927.
Personal communication Jan. 13 and May 18, 1931.
79. Loewe, G. Zur Behandlung des Wundstarrkrampfs mit Avertin. *Deutsche Zeitschr. f. Chir.*, 235: 814–819, 1932.

80. Loewe, S. Exhalationsnarkotica oder Operationsschlafmittel? *Klin. Wchnschr.*, 6: 1848–1850, 1927.
Personal communications Feb. 16, May 20, Aug. 15, Sept. 11, Sept. 17, 1931.

81. Martin, B. Das Avertin als Vollnarkotikum. *Deutsche med. Wchnschr.*, 54: 1154–1156, 1928.
Unsere heutige Kenntnis des Avertins und seine praktische Verwendung. *Deutsche med. Wchnschr.*, 54: 2068; 2110, 1928.
Die bisher bekannten angeblichen Unglücksfälle nach Avertinnarkosen (Discussion). *Zentralbl. f. Chir.*, 56: 2803, 1929.
Vollnarkosen mit Avertin. *Arch. f. klin. Chir.*, 152: 670–675, 1928.
Fortschritte auf dem Gebiete der Allgemeinnarkose. *Berl. Klin.*, 36: no. 397–398, 1–36, 1929.
Weiterer Ausbau der Avertinnarkose. *Zentralbl. f. Chir.*, 56: 72; 399, 1929.
Grundsätzliches zur Avertin-Narkose. *Schmerz*, 2: 283–289, 1929.
Die Unterbrechung der lähmenden Avertinwirkung auf das Atmungszentrum. *Zentralbl. f. Chir.*, 58: 1566–1568, 1931.
Personal communication Feb. 2, May 29, Aug. 26, 1931.

82. Martin, B., and Kotzoglu, P. Cocain als Antidot gegen Avertin. *Deutsche Ztschr. f. Chir.*, 234: 115–129, 1931.

83. Martin, E. Der Avertin-Dämmerschlaf. *Med. Klin.*, 26: 1036–1037, 1930.

84. Mintz, M. 100 Avertinbasisnarkosen (0, 1 pro 1 Kg.). *Zentralbl. f. Chir.*, 56: 2199–2200, 1929.
Ueber Avertin-Rektalnarkose. *Latvijas Artsu Z.*, no. 5–6, 56–64, 1929.
Personal communications Mar. 3, May 23, 1931.

85. Mörl, F. Coramin bei schwerster zentraler Atemlähmung in Avertinnarkose. *Med. Klin.*, 27: 916–918, 1931.
Rektale oder Dickdarmavertinnarkose? *Zentralbl. f. Chir.*, 57: 2108–2114, 1930.
Personal communication Aug. 31, 1931.

86. Momburg, F. Personal communications Feb. 2, May 18, Aug. 24, 1931.

87. Momburg, F., and Rotthaus, E. Avertindosierung. Avertin bei Tetanus. *Deutsche med. Wchnschr.*, 55: 1164–1165, 1929.

88. Mühsam, E. Rektalnarkose mit Avertin. *Schmerz*, 2: 106–129, 1928.
Vollnarkosen mit Avertin (Discussion). *Arch. f. klin. Chir.*, 152: 29–31, 1928.

89. Mühsam, R. Ueber die Avertinnarkose (Discussion). *Deutsche med. Wchnschr.*, 54: 559, 1928.
Aufgabe der Krankenpflege vor, während und nach Bauchoperationen. *Deutsche Ztschr. f. Krankenpflege*, 26: 1, 1932.
Personal communications Jan. 11, May 20, 1931.

90. Mues, O. Bericht über 630 Avertinnarkosen. *Zentralbl. f. Chir.*, 56: 2198–2199, 1929.

91. Nell, W. Ueber den Einfluss des Thyroxins auf die Avertinkonzentration im Blut. *Klin. Wchnschr.*, 11: 367, 1932.

92. Nell, W., and Sebening, W. Die Steuerungsmöglichkeit der Avertinnarkose durch Thyroxin. *Zentralbl. f. Chir.*, 52: 1569, 1931.

93. Nestmann, F. Klinisches und Pharmakologisches zur Avertinnarkose. *Klin. Wchnschr.*, 7: 1901–1904, 1928.
Erwiderung (to *Straub*, q. v.). *Klin. Wchnschr.*, 7: 2346–2347, 1928.
Personal communication Aug. 25, 1931.

94. Nissen, R. Personal communications Jan. 3, Jan. 31, May 19, Sept. 1, 1931.

95. Nordmann, O. Die Rektalnarkose mit E 107. *Zentralbl. f. Chir.*, 54: 1055–1058, 1927.
Die Rektalnarkose mit E 107. (Discussion.) *Arch. f. klin. Chir.*, 148: 97–98, 1927.
Umfrage über die Avertinnarkose. *Med. Klin.*, 24: 513–515, 1928.
Die Vorteile und Vorsichtsmassregeln der Avertinnarkose. *Therap. d. Gegenw.*, n. F. 41: 442–447, 1929.
Die bisher bekannten angeblichen Unglücksfälle nach Avertinnarkosen. *Zentralbl. f. Chir.*, 56: 2798–2803, 1929.
Die bisher veröffentlichten Todesfälle nach Avertinnarkose. *Chirurg*, 1: 1142–1153, 1929.
Erwiderung (to Behrend, q. v.). *Chirurg*, 2: 73, 1930.
Personal communications Jan. 16, Feb. 19, June 9, Aug. 29, 1931.

96. Payr, E. Personal communications Jan. 19, July 6, Sept. 9, 1931.

97. Pels-Leusden, F. Personal communications Jan. 28, Feb. 24, June 24, July 6, Sept. 3, 1931.

98. Penkert, M. Personal communications Feb. 18, May 19, Sept. 3, 1931.

99. Pfister, G. Beobachtungen und Versuche über die Avertinbasisnarkose. *Arch. f. klin. Chir.*, 165: 402–424, 1931.

100. Plettner, F. Personal communications Jan. 20, June 21, 1931.

101. Poppert, P. Personal communications Feb. 3, May 26, 1931.

102. Pribram, B. O. Die Steuerungsmöglichkeit der Avertinnarkose durch Thyroxin. *Deutsche med. Wchnschr.*, 55: 1457–1458, 1929.
Zur Avertinnarkose. *Zentralbl. f. Chir.*, 56: 1164–1168, 1929.
Die Steuerungsmöglichkeit der Avertinnarkose durch Thyroxin. *Zentralbl. f. Chir.*, 56: 3138–3142, 1929.
Personal communications Mar. 12, Apr. 4, May 19, Sept. 2, 1931.

103. De Quervain, F. Personal communications Jan. 30, May 19, 1931.

104. Ranzi, E. (Innsbruck). Personal communications Feb. 3, May 19, Sept. 9, 1931.

105. v. Redwitz, E. Ueber den derzeitigen Stand der Avertinnarkose (Discussion) *Zentralbl. f. Chir.*, 55: 489, 1928.
Personal communications Feb. 10, June 5, Aug. 24, 1931.

106. Reichsmedizinalkalender, 1931.

107. Richet, C. fils, and Joly, F. Traitement des delires par le tribrométhanol. *J. de méd. de Paris*, 52: 14–18, Jan. 7, 1932.

108. Riedel, I. Untersuchungen über Beeinflussung der Dauer der narkotischen Avertinwirkung. *Arch. f. exper. Path. u. Pharmakol.*, 148: 111–118, 1930.

109. Roedelius, E. Die Avertinnarkose. *Deutsche med. Wchnschr.*, 53: 2067, 1927.
110. Ruge, E. Avertinbetäubung. *Med. Welt*, 2: 873–875, 1928.
Umfrage über die Avertinnarkose (Discussion). *Med. Klin.*, 24: 617, 1928.
Personal communications Feb. 23, May 18, Aug. 24, 1931.
111. Sauerbruch, F. Avertin—wie Lachgasnarkose sind noch weit davon entfernt die gute altbewährte Aethernarkose aus der Chirurgie zu verdrängen. (Discussion.) *Zentralbl. f. Chir.*, 56: 1767–1768, 1929.
112. v. Scanzoni, C. Todesfälle bei Avertinrektalnarkosen. *Zentralbl. f. Chir.*, 58: 2251–2256, 1931.
113. Schaefer, V. Der Wundstarrkrampf und seine Behandlung unter Berücksichtigung der Schrankensysteme des Zentralnervensystems. *Deutsche Ztschr. f. Chir.*, 231: 533, 1931.
114. Schloffer, H. (Prag). Personal communications Sept. 3, Sept. 15, 1931.
115. Schmidt, H. Das Ephedrin in der operativen Praxis. *Zentralbl. f. Chir.*, 55: 3207–3209, 1928.
Ueber Avertinnarkose (Discussion) *Zentralbl. f. Chir.*, 56: 1004–1005, 1929.
Personal communications Mar. 20, May 19, Aug. 24, 1931.
116. Schmieden, V. Personal communications Jan. 15, Feb. 13, May 19, Aug. 27, 1931.
117. Schnitzler, F., (Vienna), Personal communications Jan. 19, May 20, 1931.
118. Schrödl, P. Ueber einen Todesfall in Avertinnarkose. *Zentralbl. f. Chir.*, 55: 1231–1233, 1928.
119. Schulze, W. Ueber Rektalnarkosen mit Avertin-Amylenhydratlösung. *Deutsche med. Wchnschr.*, 54: 1928–1929, 1928.
Ueber Mastdarmbetäubung. *Deutsche Ztschr. f. Chir.*, 220: 121–125, 1929.
Ueber Mastdarmbetäubung. *Zentralbl. f. Chir.*, 56: 2752, 1929.
Vollnarkosen mit Avertin-Magnesiumsulfat-Narkophin. *München. med. Wchnschr.*, 77: 1312–1314, 1930.
Avertin-Magnesiumsulfat-Narkophin-Narkose nach Martin. *Schmerz*, 4: 59–70, 1931.
Personal communication June 20, 1931.
120. Sebening, W. Die Avertinnarkose. *Zentralbl. f. Chir.*, 56: 2074–2076, 1929.
Vollnarkosen mit Avertin (Discussion). *Arch. f. klin. Chir.*, 152: 37–41, 1928.
In welchem Darmabschnitt wird das Avertin wirksam absorbiert? *Zentralbl. f. Chir.*, 57: 1539–1540, 1930. Erwiderung, L. Treplin (q.v.).
Physiologische Grundlagen der Avertinnarkose. *Schmerz*, 2: 403–439, 1930.
121. Seefisch, G. Vollnarkosen mit Avertin (Discussion). *Arch. f. klin. Chir.*, 152: 35–37, 1928.
Personal communications Feb. 3, Mar. 5, May 18, Sept. 22, 1931.
122. Sievers, R. Ueber die Avertin- (E 107) Narkose im Kindesalter. *Deutsche med. Wchnschr.*, 53: 1253–1255, 1927.
Vollnarkosen mit Avertin (Discussion). *Arch. f. klin. Chir.*, 152: 31–33, 1928.
Die Avertinvollnarkose im Kindesalter. *Zentralbl. f. Chir.*, 56: 194–204, 1929.
Ueber Wesen und Bedeutung der Intervallmethode für die Avertinnarkose im Kindesalter. *Arch. f. klin. Chir.* 164: 66–94, 1931.
Die Betäubungsmethoden im Kindesalter. *Fortschr. d. Therap.* 7: 684–693, 1931.
Personal communications Jan. 2, May 18, Sept. 1, 1931.
123. Sioli, F. and Neustadt, R. Avertin, (E 107) in der Psychiatrie. *Klin. Wchnschr.*, 6: 1851–1852, 1927.
124. Smidt, H. Personal communications Jan. 30, May 30, Aug. 28, 1931.
125. Specht, K. Ueber Avertinnarkose bei Leber-und Nierenschädigungen. *Zentralbl. f. Chir.*, 56: 2213–2217, 1929.
Zur Beurteilung der Wirkungsweise des Avertin. *Zentralbl. f. Chir.*, 57: 459–463, 1930.
Coramin bei Avertinnarkose. *Zentralbl. f. Chir.*, 59: 1345, 1932.
126. Stahnke, E. N. Ueber Schmerzbetäubung in der operativen Gynäkologie und Geburtshilfe. *Monatschr. f. Geburtsh. u. Gynäk.*, 87: 144–171, 1931.
Personal communications Sept. 14, Dec. 12, 1931.
127. Starlinger, F. Schmerzverhuetung. Zwoelf Vorlesungen. Monograph. Wien, 1931.
128. Stemmler, W. Der Dämmerschlaf in der Bauchchirurgie. *Deutsche Ztschr. f. Chir.*, 203–204: 287–302, 1927.
129. Stich, R. Personal communications Jan. 20, May 20, 1931.
130. Straub, W. Rektalnarkose mit Avertin. *München. med. Wchnschr.*, 75: 593–595, 1928.
Rektalnarkose mit Avertin. ii. Ausscheidung und Nebenwirkungen. *München. med. Wchnschr.*, 75: 1279–1281, 1928.
Klinisches und Pharmakologisches zur Avertinnarkose. Bemerkungen zu der Mitteilung von F. Nestmann. *Klin. Wchnschr.*, 7: 2346, 1928.
Personal communication Sept. 2, 1931.
131. Stuber, B. Klinische Physiologie. München, Bergmann, 1931.
132. Sudeck, P. Personal communications Feb. 6, May 18, 1931.
133. Treplin, L. In welchem Darmabschnitt wird das Avertin wirksam resorbiert? *Zentralbl. f. Chir.*, 57: 1275–1276, 1930.
134. Uebelhör, R. Experimentelle Untersuchungen über die Beeinflussung der Avertinnarkose. *Zentralbl. f. Chir.*, 57: 2358–2363, 1930.
135. Uhlmann, F. Ueber Coramin. *Ztschr. f. d. ges. exper. Med.*, 43: 556–583, 1924.
136. Unger, E. Personal communications Feb. 11, Sept. 2, 1931.
137. Unger, E. and May, H. Elektrokardiographische Untersuchungen während der Narkose (insbesondere Avertinnarkose). *Zentralbl. f. Chir.*, 54: 3272–3273, 1927.
138. Voelcker, F. Personal communications Feb. 14, July 29, 1931.
139. Welsch, A. Chemische Untersuchungen zur Avertinfrage. *Arch. f. exper. Path. u. Pharmakol.*, 139: 302–312, 1929.

140. Wessely. Ueber unsere bisherigen Erfahrungen mit der rectalen Avertinnarkose bei Augenoperationen. *Klin. Monatsbl. Augenheilk.*, 81: 862, 1928.

Die Bedentung der Avertinnarkose für die Augenheilkunde. *Ztschr. f. Augenheilk.*, 100–101: 556, 1929.

141. Westphal, K. Avertinbehandlung einer schweren Chorea. *München. med. Wchnschr.*, 77: 1104–1105, 1930.

142. Wiedhopf, O. Die Behandlung des Wundstarrkrampfes mit grossen intravenoesen Heilserummengen. *Deutsche Ztschr. f. Chir.*, 232: 105, 1931.

Personal communications Jan. 6, Feb. 12, May 21, Aug. 25, 1931.

143. Willstätter, R. and Duisberg, W. Zur Kenntnis des Trichlor- und Tribrom-äthylalkohols. *Ber. d. deutsch. chem. Gesellsch.*, 56: 2283–2286, 1923.

144. Wolf, A. Avertin bei Wundstarrkrampf. *Zentralbl. f. Chir.*, 56: 2200–2202, 1929.

145. Wuelfing, M. Die Rueckatmungsnarkose nach Ombredanne zur Ergaenzung der rektalen Avertinnarkose (zugleich ein Bericht ueber Erfahrungen bei 1200 Avertinnarkosen). *Med. Klin.*, p. 655, 1931.

146. Wymer, I. Die Säure-Basenverhältnisse bei der Rektalnarkose mit E 107. *Zentralbl. f. Chir.*, 54: 2459, 1927.

147. Wymer, I., and Fuss, H. Eine vergleichende Studie über die Säurebasenverhältnisse bei der Aether-Chloroform- und Avertin-Narkose. *Narkose u. Anesth.*, 1: 283–292, 1928.

REFERENCES OF DR. NIXON*

17. Speed, K. Fractures and Dislocations. Phila., Lea & Febiger, 1928.

18. Speed, K. Plaster embedded skeletal traction. *Surg. Gynec. Obst.*, 51: 854–856, 1930.

19. Steinmann, F. A new extension method in the treatment of fractures. *Zentralbl. f. Chir.*, 34: 938–942, 1907.

20. Steinmann, F. Present stage of nail extension. *Archiv. f. klin. Chir.*, 89: 1130–1136, 1909.

21. Steinmann, F. The history of the peg or nail extension treatment of fractures. *Ztschr. f. Orthop. Chir.*, 29: 96–114, 1911.

22. White, J. W. Simplified method for tibial lengthening. *J. Bone & Joint Surg.*, 12: 90–96, 1930.

23. Zierold, A. Reaction of bone to various metals. *Arch. Surg.*, 9: 365–412, 1924.

* Continued from p. 455.

UNUSUALLY LARGE URETER STONES*

A REPORT OF TWO CASES

HERMAN L. KRETSCHMER, M.D.

CHICAGO

THE literature dealing with the diagnosis and the treatment of ordinary stone in the ureter is voluminous. On the other hand, case reports of unusually large stones in the ureter are relatively few, and it is because of their rare occurrence that I wish to present the following two cases.

FIG. 1. Case I. Calculus extending from ureterovesical junction to fourth lumbar vertebra.

CASE I. Dr. S. L. B., male, aged thirty-eight years, entered the Presbyterian Hospital March 16, 1922.

Previous History. Fifteen years previous to admission patient had an attack of right renal colic. An operation was performed but no stone was found.

Thirteen years ago, or two years after the before-mentioned attack of renal colic, a severe pain in the bladder occurred; there was a sudden stoppage of urine, followed by complete retention. A suprapubic cystotomy was done and a bladder stone removed.

FIG. 2. Case II. Enormous calculus in lower end of right ureter.

Present Complaint. Pyuria. The urine has been turbid since the second operation and on examination a large amount of pus was found.

Frequency of Urination. This has been present during the past year, but during the past three months has not been apparent.

Pain in the Bladder. Pain in the region of the bladder radiates to the left thigh and into the kidney. It is periodical and recurs at indefinite intervals. At first relief was obtained by remaining in bed but at present the pain is intensified when the patient remains in bed.

Pain on Urination. Pain is sometimes severe during urination and sometimes continues after urination for a short space of time

* From the Presbyterian Hospital and Rush Medical College of The University of Chicago.

—several seconds. It is severe enough to cause intense discomfort.

Physical Examination. Head and neck, negative. Heart and lungs, negative. Examination of the abdomen reveals a right nephrotomy scar and a midline suprapubic one; otherwise negative. External genitalia, negative. Rectal examination shows the prostate to be small and slightly increased in consistency.

Blood Examination. Leucocytes 14,400; hemoglobin 84 per cent.

Blood Pressure. Systolic 122, diastolic 80.

Wassermann Test negative.

Blood Chemistry. Urea nitrogen 50.0; uric acid 2.2; creatinin 1.5; Non-protein nitrogen 48.0.

Urinalysis. Albumin +, blood +, sugar 0, red blood cells +.

Roentgen-ray Examination. On the left side, a dense shadow occupies the position of a dilated ureter and extends from the fourth lumbar downward into the pelvis (Fig. 1). Three very small shadows are in the pelvis, suggesting calcification of the arteries. Negative for bone change.

Cystoscopic Examination. Right ureteral orifice, normal. Right ureter catheterized without difficulty or obstruction. Left ureteral orifice, elevated; a catheter enters but it is impossible to advance the catheter, due to the presence of a stone in the ureter. Examination of the urine obtained at this examination shows:

	Leucocytes per Cu. Mm.	Cultures
Bladder	6400	Colon bacilli & staphylococci
Right kidney	20	Sterile

Phthalein Test. Bladder: first one-half hour 36 per cent; second one-half hour 12 per cent; Total 48 per cent.

Right Side: first one-half hour 18 per cent.

Operation, March 29, 1922. The patient was advised to have a nephroureterectomy but consented to a ureterotomy and the removal of the stones. An extraperineal ureterotomy was done and the stones removed.

Result. Recovery uneventful. Discharged from the hospital April 21, 1922.

Case II. D. C. G., male, aged sixty-four years, entered the Presbyterian Hospital, March 4, 1923.

Fig. 3. Case II. Ureter stone after removal.

Previous History. Fifteen years previous to entering the hospital the patient suffered over a period of three years from a severe pain in the left side which radiated down into the penis. These attacks came on about once a month, lasted a day or two following which pus was found in the urine. Roentgen-ray examination at that time was negative for stone.

Present Complaint. Hematuria. Six months before admission the patient noticed blood in the urine, generally decidedly bloody, and at times well mixed with urine. He also passed large clots of blood. The hematuria was intermittent in character, sometimes mild and at other times very severe.

Frequency of Urination. This began at about the same time and has gradually increased in severity. At the present time it is necessary to void as often as ten times during the day and from two to four times at night.

Pain in the Penis. This symptom has been present for six months; it is aggravated by bending forward and also when descending the stairs.

Burning on Urination. This disturbance has been present over a considerable length of time; during the last four or six weeks it has increased in severity, at times being extremely painful.

Difficulty in Starting the Stream. For about six weeks, following catheterization

for the examination for residual urine, difficulty was a daily occurrence.

Physical Examination. Patient is well nourished and appears not to be acutely ill. Head and neck, negative. Eyes react to light and accommodation. Tonsils, atrophic. Liver, palpable 2 cm. below costal arch. Spleen and kidneys not palpable. External genitalia, negative. Rectal examination shows a moderative hypertrophy of both lateral lobes. The margins are smooth and sharply defined. No signs of carcinoma.

Blood examination: Leucocytes 7800; hemoglobin 82 per cent.

Blood chemistry: Urea 30.0; uric acid 3.8; creatinin 1.55; non-protein nitrogen 28.0.

Urinalysis. Albumin +, blood +, sugar 0, leucocytes +++, red blood cells ++.

Roentgen-ray Examination. There is an oval shadow in the region of the bladder, compatible with stone. Another shadow, heavier than bone, suggests an enormous calculus in the lower end of the ureter (Fig. 2).

Cystoscopic Examination. Intravesical hypertrophy of the prostate. Behind the prostate a stone about the size of an unshelled almond. An attempt was made to catheterize the left ureter, but an obstruction was met 1 inch up. Examination of the urine obtained at this examination shows: Bladder: leucocytes per c. mm. 7560; cultures, colon bacilli.

Cystogram. A good filling of the bladder. The solution hides the stone which on earlier films was seen low in the pelvis. A very dense shadow is seen projecting beyond the shadow of the solution.

Phthalein Test. Time in appearance, five minutes; first half hour, 29 per cent; second half hour, 18 per cent; second hour, 10 per cent; total two hours, 57 per cent.

Operation (general anesthesia), March 16, 1923. A suprapubic cystotomy was done. The stone was removed from the bladder and an intra-urethral enucleation of the prostate was carried out. The stone in the ureter was removed by a ureterotomy (Fig. 3).

Result. Recovery uneventful. Discharged from the hospital, April 8, 1923.

Examination of Bladder Stone. A white easily powdered stone. Chemical examination shows this stone to consist of a mixture of calcium phosphate and calcium oxalate, the former predominating, together with a small amount of organic detritus.

Examination of Ureter Stone. A brownish black, rough, irregular stone of hard consistency. Chemical examination shows this stone to consist largely of calcium oxalate with some calcium phosphate mixed with a large amount of organic detritus.

Recurrence. The patient was again admitted to the Presbyterian Hospital, January 28, 1931, eight years after the previous operation. No symptoms were present but he reentered the hospital because he was told by an insurance company physician that his urine contains pus.

Physical Examination. Negative. Rectal examination, negative.

Urinalysis. Albumin 0, blood 0, sugar 0, pus +++.

Roentgen-ray Examination. A shadow in the region of the left ureter. This shadow is an exact duplicate of the shadow found in the left ureter, March 10, 1923.

Remarks. Recurrence of stone. The shadow is identical with the shadow seen before the stone was removed (Fig. 2).

The patient refuses to undergo treatment as he has no symptoms.

COMMENTS

The management of cases of stone in the ureter may be discussed under four headings: (1) Cases in which the stone is small so that in all probability it will pass without cystoscopic manipulation and without surgery. In other words, in a certain number of cases the roentgen-ray examination shows the presence of stone, but from the size of the stone it is reasonable to assume that it will pass without cystoscopic manipulation, especially if it moves after each attack of renal colic, as demonstrated in the *x*-ray film.

(2) In this group may be placed cases in which the stone is of a larger size than in Group 1. In this group we may also discuss cases in which the stone apparently is slow in its descent. Patients belonging to this group may be advised to have cystoscopic manipulation, that is, the use of the ureteral catheter to dislodge the stone, the passing of large catheters or bougies for purposes of dilatation, and the

use of oil injections through the catheter to aid the stone in its descent.

(3) In this group are the somewhat larger stones, hence the choice between cystoscopic manipulation and surgery calls for careful consideration. In dealing with this group excellent results may be obtained by means of the former method, and a stone, moderately large, is often passed where one hardly dares to hope for such a termination.

(4) This group contains cases in which the stone is of such size that the patient is obviously a subject for surgery.

Instances of large ureteral stones have been reported by Kidd, Bugbee, Carsons, Federoff, Fryszman, Stevens and others.

In Collinson's case two calculi with a total weight of 83.2 gm. formed a complete cast of the ureter. Federoff's case showed a stone 10 cm. long, weighing 52 gm., and practically filling the ureter.

The cases reported by Harris and Stevens were unique in that giant calculi were bilateral.

Kidd operated for the removal of a calculus 2½ inches long by 1 inch in width, weighing 1 oz., which had occasioned few symptoms. In discussing this fact the author states that, as a rule, the larger the size the fewer symptoms produced by the stone. Of interest in this regard is Reshower's case where at no time was the left ureter (the site of a giant calculus removed by ureterotomy) obstructed, while the right ureter was obstructed, with resultant hydronephrosis, by a small calculus (freed by cystoscopic manipulation). Harris notes that a number of giant ureteral calculi on record have failed to produce symptoms.

In some cases large ureteral calculi have been successfully removed by ureterotomy. In others, the condition of the kidney and the presence of infection have made ureteronephrectomy necessary.

REFERENCES

Buerger, L. Unusually large ureteral calculus. *N. York M. J.*, 100: 1103, 1914.

Bugbee, H. G. Silent ureteral calculi. *Trans. Am. Ass. Genito-Urin. Surg.*, 1930, pp. 173–176.

Carsons, W. J. Giant ureteral calculi. *Ann. Surg.*, 91: 141; 143, 1930.

Collinson, H. Notes on 4 cases of ureteral calculi, in one of which a complete case of the ureter was present. *Lancet*, 185: 1456, 1913.

Crowell, A. J. Removal of ureteral stones by cystoscopic manipulation. *J. Urol.*, 6: 243; 2651, 1921.

Federoff, S. Zur Kasuistik der Ureter Steine. *Ztscbr. f. Urol.*, 3: 65, 1909.

Fryszman, A. Uber ein ungewohnlich grossen Neiren-Harnleiterstein. *Ztscbr. f. Urol.*, 25: 333–334, 1931.

Grossmann, W. Ein ungewohnlich grossen Harnleiterstein. *Zentralbl. f. Gynäk.*, 55: 2964, 1931.

Harris, A. Giant bilateral ureteral calculi. Am. J. Surg., n.s. 10: 362–366, 1930.

Jefferson, J. C. A large ureteral calculus. *Brit. M. J.*, 1: 14, 1928.

Kidd, F. Calculus of unusual size. *Lancet*, 198: 150–151, 1920.

Patch, F. S. A giant ureteral calculus. *Canadian M. A. J.*, 23: 553–555, 1930.

Putzu, F. Giant calculus of pelvic ureter, extracted by classical iliac section. *Arcb. ital. di urol.*, 5: 443–452, 1929.

Reshower, I. C. An unusual ureteral stone. Am. J. Surg., n.s. 2: 386, 1927.

Squires, C. B. Disposition of ureteral calculi at the Crowell Clinic from 1915 to March 31, 1930. *J. Urol.*, 24: 461, 1930.

Stevens, W. Unusual urinary calculi. *Calif. & Western Med.*, 28: 203, 1928.

Walters, W. Unusual number of large stones in the lower portion of the ureter. *S. Clin. N. Amer.*, 9: 913, 1929.

PREVENTION OF THE RECURRENCE OF URINARY CALCULI*

ALEXANDER RANDALL, M.D.

PHILADELPHIA

I WISH to present a preliminary report of some work which I have been doing in an effort to avoid that unpleasant surgical sequence where, after the removal of a renal calculus, a recurrence of stone rapidly follows.

I believe we are now ready to agree that in the kidney, as in the bladder, calculus disease is no longer a disease at all, but a symptom. No matter how difficult a surgical problem may grow out of the presence of renal lithiasis, fundamentally, its permanent relief is not to be sought in the simple removal of the stone but demands at the same time an appreciation and correction of the condition which allowed of its formation. So let us look at the factors on which can be placed some reliance as being causative:

First: Urinary stasis takes its place in renal stone formation in equal force and importance as is granted to it in bladder stone. Faulty drainage and urinary stagnation is the essential preparation of the field, possibly present in an unappreciated large proportion of persons, and only awaiting the turn of events for the second link to be forged in the development of the chain of circumstances on which hangs the ultimate development of a calculus growth.

Second: The problem of the chemical character of calculus formation becomes increasingly intricate as one delves into it. No one hypothesis can be stretched to fit all cases. We are practically forced to acknowledge that the chemical change that allows a pure uric acid calculus to form, must differ from that whence an oxylate stone crystallized. As the chemical results vary, so must the chemical cause.

Third: The role played by infection must be separated into its component parts. If it can be proved absent, stasis and chemical changes remain to us. If it be present, it may be expected to vary its influence in accordance with the individual behavior of the specific organism's habits.

Testing these fundamental ideas against our experience with clinical cases has led me to feel that in one variety of stone we are apparently approaching some understanding of its causative factors. This is the so-called earthy, or triple phosphate stone.

Ever since Marcet and Sheele did their early chemical analysis of urinary calculi, we have recognized their observation that once the formation of deposits of triple phosphate takes place, it is very rarely superseded by other salts. Again, this variety is known to be the cause of both the large and the rapidly growing calculi. To these characteristics I believe can be added the observation that once a triple phosphate stone is removed, subsequent stone formation will be of a similar chemical character. I believe these characteristics to depend upon the behavior of certain infecting organisms, and on this basis have evolved a step in preventive therapy, thoroughly tested in allied conditions in the lower urinary tract, checked by laboratory methods for efficiency and safety, and aimed to control and to prevent the infection responsible for this variety of stone.

It is recognized that bacteria often have a very limited range of chemical reaction in which they normally thrive. Change their cultural habitat in this one factor, and bacteriostatic, or bacteriocidal, action is obtained.

* From the Department of Urology, Hospital of the University of Pennsylvania. Read before the Section on Genito-urinary Surgery, N. Y. Academy of Medicine, April 20, 1932.

There is a recognized group of organisms which regularly produce, and then flourish in an alkaline urine, and in this media carried out the following steps in our clinical material in an effort to obtain a prevention of the infection by changing

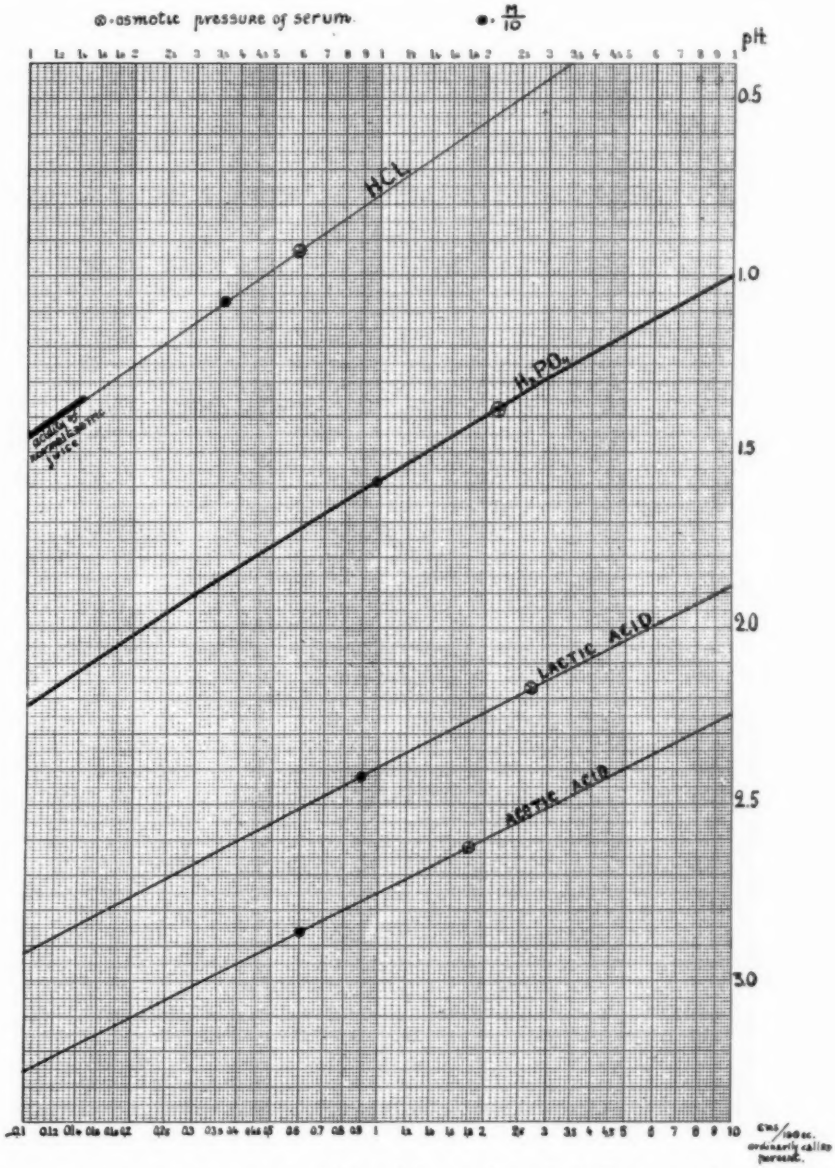


Fig. 1. Comparative curves of four weak acids, giving point of similar osmotic pressure to serum, point of $\frac{M}{10}$, and on right the pH value or acidity, while below is percentage strength or alkali binding capacity.

find a suitable habitat wherein they rapidly change urea into ammonia, with a resulting precipitation of the alkaline inorganic salts of calcium, magnesium and ammonia, of which the characteristic phosphatic calculi are formed.

In order to control this chemical change in the urine favorable for bacterial growth and phosphatic precipitation, we have the chemistry of the urine, and in so doing creating a habitat in which bacteria responsible for the same will not grow.

Our first step was in the treatment of suprapubic fistulae following cystostomy with subsequent drainage. The picture is familiar to you all of the postoperative prostatic patient, whose wound breaks down, creating a surgical menace, that is

a marked detriment to normal healing and closure. These wounds appear to be essentially related to an alkalinization of the urine, and at their worst present an ugly, sloughing gangrenous sore on whose walls and even on the abdominal skin there is likely to be deposited encrustations of phosphates. Some time ago we experienced the ease with which such encrustations could be removed, in fact dissolved, by the topical application of a 5 or 10 per cent phosphoric acid solution. The response in healing following such local treatment is marked; a healthy wound rapidly follows the separation of the ugly slough, with the complete disappearance of phosphatic encrustations. Even in the absence of such breaking-down of the wound, an ammoniacal odor appearing in the dressings, to the initiated, is a warning that trouble is in store. Since adopting this step, the handling of such bladder cases by the topical application of this weak acid solution has made this complication gratifyingly infrequent.

The second step in our clinical handling of these cases was in certain patients where, though the bladder wound was saved from the threatened breaking down, nevertheless, the constant threat of such a possibility was evident in the persistent pool of alkaline urine draining from the bladder. No amount of acidifying drugs by mouth appears to be sufficient in these cases to change the reaction of such an alkaline urine to a normal acidity, while topical applications to the fistula orifice fail of sufficient penetration to reach the bladder urine. It was in such a case, some time ago, that I first attempted a direct irrigation of the bladder cavity with a solution of 1 per cent phosphoric acid. To our surprise it became evident that the bladder not only tolerated this solution without discomfort, but even a stronger solution could be used without marked irritation being experienced by the patient. One or two such irrigations caused a prompt return of normal bladder urinary acidity, and this once obtained it was easily held by the administration of the acidifying drugs by mouth.

This improvement in the handling of these cases has since become a routine in all our suprapubic cystostomies, and I feel it is a definite step in advance in controlling the possibility of postoperative infection with the type of organism which is recognized to have the foregoing characteristics of both alkalinizing the urine and causing a precipitation of the earthy phosphates.

This finding in the lower urinary tract naturally led to our third step in attempting to accomplish the same end in cases of recurrent calculi in the upper urinary tract. As stated before, these stone repeaters practically always form phosphatic stones, and with this in view, I wish to report to you our experiences to date in 11 cases in which we have irrigated the renal pelvis postoperatively with phosphoric acid solution. It is my hope that by so doing we can cause a sterilization of the infection with the organisms which have the afore-described characteristics if they be present, or be a prophylactic against their implantation. Such, I feel, to be a justifiable step towards the prevention of recurrent phosphatic calculus in the upper urinary tract.

In acidifying the urinary passages by irrigation, three qualities are desired in the acid chosen: (1) It should not have to be used in a concentration which would have an osmotic pressure greatly above that of serum for so it would tend to irritate the mucosa by its dehydrating effect. (2) It should have as high an alkali binding capacity as possible to minimize the neutralization by alkali or buffers in the cavity. (3) It should have as high an acidity as the tissues will tolerate.

Phosphoric acid in concentration of 1 gm. per 100 c.c. is approximately 0.100 molar, has a pH about 1.5 to 1.6 and possesses 46 per cent of the osmotic pressure of the serum. This acidity, pH 1.6, is somewhat less than that of normal stomach contents after a test meal which, with a free HCl of 40, have a pH of about 1.4. A solution of hydrochloric acid having the

same pH of 1.6 has a concentration of only 0.019 molar and hence has only 1/5 the alkali binding power of phosphoric acid at this same pH.

Lactic acid at a concentration of 2.7 gm. per 100 c.c. has an osmotic pressure equal to serum but a pH of only 2.2, about one-sixth as acid as phosphoric acid of the same concentration; indeed even at 10 per cent concentration the pH of lactic acid is only 1.9.

Acetic acid is still weaker and when at a concentration of 1.8 gm. per 100 c.c., which has an osmotic pressure equal to serum, its pH is only 2.6; even at 10 per cent concentration its pH is only 2.2. It has about one-thirteenth the acidity of a phosphoric acid solution of the same concentration.

It follows that both acetic and lactic acids are too weak to be suitable for an irrigating solution. On the other hand, a solution of hydrochloric acid will have this pH at so low a concentration that it has only one-fifth the alkali-binding capacity of the corresponding phosphoric acid.

Of these four acids only phosphoric acid fulfills the requirements for an irrigating solution with pH of about 1.6.

Experiments on dogs' kidneys have been performed and repeated by injecting the pelvis through the ureter from a laparotomy incision with a 1, 3 and 5 per cent phosphoric acid solution. One kidney was removed immediately, and the second one removed at the end of forty-eight hours. We have not been able to demonstrate, on microscopic study of these experimental dogs' kidneys, any evidence of damage to the pelvic epithelial lining or the renal papillae; nor is there any evidence in these sections of any caustic action from the use of the drug in the afore-named strengths.

CASE REPORTS

Case 1. S. N., male, white, aged thirty-eight years. In September, 1925, the patient was suddenly taken with an attack of left ureteral colic. A diagnosis of left ureteral stone was made, and a left ureterolithotomy was performed.

Three months later, December, 1925, he experienced a dull pain in the right loin which was subsequently diagnosed as stone in the right kidney. He was again operated upon and seven small stones removed. Subsequent to this he spontaneously passed two small stones.

For the next four years he had mild attacks of right renal pain, lasting from two to six hours. During this interval he was twice admitted to other hospitals for study, but on each occasion he refused operation, and apparently all that was done was a catheter drainage of the kidney, with the subsidence of chill and fever which had accompanied each attack.

His first admission to the University Hospital was on July 17, 1930. Study showed a ureteral calculus in the lower third of the right ureter. After several attempts to aid the stone's passage, a right ureterolithotomy was performed on July 25, 1930, under spinal anesthesia. Convalescence was uneventful and he left the hospital on August 12, 1930. A follow-up cystoscopic examination, on September 8, 1930, showed no obstruction to the right ureter, though the pelvic urine was loaded with pus cells, and a lavage with 1 per cent mercurochrome solution was performed. The patient was re-admitted in November, 1930, remaining in the hospital four days for study. Diagnosis: Right pyelitis, with an *x*-ray shadow suspicious of right renal calculus.

He was again admitted to the hospital in January, 1931, for seven days, complaining of constant right-sided pain radiating down the line of the right ureter. At this time a purulent right pelvic urine was obtained. An *x*-ray plate suggestive of a shadow in the right kidney region was obtained, while low in the ureter appeared an oval shadow similar to that seen in the plates at the time of his right ureterolithotomy. There was no obstruction to catheter passage, nor in the previous, or this admission had there been any fever. His next admission was three months later, in March, 1931, when a more complete study was allowed and a recurrence of his calculus in the lower right ureter substantiated. Two operations were attempted at this time and both failed: the first, from an inability to satisfactorily expose the lower third of the ureter extraperitoneally; and the second, when this was successfully done, the stone was

found to have migrated away from the field of attack.

After further attempts at dilating the lower ureter in the hope that this stone would pass spontaneously, the final operation was performed in October, 1931, and the stone removed from the upper third of the ureter after fixing it by an indwelling catheter. A tube was placed in the ureter up to the pelvis and the wound closed about it. The pelvis was daily irrigated with 1 per cent phosphoric acid and on one occasion a 3 per cent solution was used. There was no evidence of any local disturbance or pain, and when the tube was removed on the eighth postoperative day, primary closure of the wound rapidly followed.

Following his discharge, the patient has reported regularly at intervals of two weeks for right pelvic lavage and ureteral dilatation. During his stay in the hospital, and subsequent to his discharge, he has been put on the regular administration of a dram of cod liver oil twice daily, and urged to continue a diet containing large quantities of milk and eggs. On January 8, 1932, his right pelvic urine was clear of pus, but still weakly alkaline; while on February 23, 1932, it was sterile to culture, and of a pH 6.5. On April 30, 1932, the right pelvic urine was still alkaline to litmus and had a pH of 7.4, while the left pelvic urine was acid to litmus and had a pH of 5.7. This case is still under observation.

Tabulation of Cases

No.	Name	Operations	Chemistry	Pelvic Lavage	Drain Removed	Ureteral Lavage	Final Studies
1.	S. N.	1. L. Ureterolithot. 2. R. Nephrolithot. (Voided calculi) 3. R. Ureterolithot. 4. R. Ureterolithot.	Ca. & mg. phos. Ca. carbon.	Daily 1% sol. phosphoric acid Once 3% sol.	8th p.o. day	Every 2 weeks	4 mos. later R. pelvic urine pH 6.1 7 mos. later R. pelvic urine pH 7.4 L. pelvic urine pH 5.9
2.	G. E.	1. R. Pyelolithot.	Uric acid Ca. carbon.	Q.2.d.1% sol.	11th p.o. day	Every 2 weeks	6 mos. later R. pelvic urine pH 6.0
3.	J. W. L.	1. R. Ureterolithot. 2. L. Pyelolithot. 3. L. Pyelolithot. 4. R. Ureterolithot. 5. R. Ureterolithot. R. Pyelolithot. R. Nephrolithot.	Ca. & mag. phos. Ca. oxylate Ca. carbon	Q.2.d.1% sol. Once 2% sol.	21st p.o. day	Every 3 weeks	5 mos. later R. pelvic urine pH 5.8 Has coral calculus in L. pelvis
4.	K. S.	1. L. Pyelolithot.	Ca. carbon. Na. urate	Daily 1% sol.	17th p.o. day	None	2 mos. later L. pelvic urine pH 5.3
5.	S. D.	1. R. Pyelolithot.	Ca. carbon. Triple phos.	Daily 1% sol.	20th p.o. day	None	
6.	F. T.	1. R. Uretero-lithot.	.....	Once 1% sol.	4th p.o. day	Every 2 weeks	
7.	M. G.	1. L. Nephrolithot. 2. R. Nephrolithot. 3. R. Nephrolithot. permanent drain	Triple phosphate	Twice daily for 4 days	Not removed	None	Encrusted nephrotomy sinus. Strong ammoniacal odor. Uremia. Death
8.	H. H.	1. L. Pyelolithot. 2. L. Pyelolithot.	Na. urate Ca. carbon	Daily 1% sol.	17th p.o. day	None	
9.	J. A.	1. R. Pyelolithot.	Ca. carbon.	Q.2.d.1% sol.	6th p.o. day	None	
10.	S. F.	1. R. Pyelolithot.	Ca. carbon. Na. urate Uric acid	Daily 1% sol.	5th p.o. day	None	2 mos. later R. pelvic urine pH 6.0
11.	H. B.	Congenital solitary kidney 1. R. Pyelolithot. R. Nephrolithot.	Ca. oxylate Ca. carbon.	Every other hour for one hour. 1% sol.	23rd p.o. day	None	Fragment in pelvis postoperatively. Attempted to dissolve it to no avail. Removed with forceps on 23rd p.o. day

His recent calculus was composed of calcium and magnesium phosphate and calcium carbonate.

Case II. G. E., male, white, aged thirty-six years, admitted to the University Hospital, November 6, 1931. Diagnosis: Calculus in the right renal pelvis. This calculus occurred in an intrarenal pelvis and at operation difficulty was experienced in getting sufficient exposure for the total removal of the stone, so that during traction the calculus broke and numerous fragments were obtained after careful search. A tube was inserted in the pelvis and the wound closed about the drainage. The pelvis was irrigated daily with a 1 per cent mercurochrome solution, alternating with a 1 per cent phosphoric acid solution. The tube was removed on the eleventh postoperative day. The patient was discharged on November 26, 1931.

Since the date of his discharge the patient has reported at two-week intervals for renal pelvic lavage with phosphoric acid and has been placed upon a diet rich in vitamin A, and cod liver oil in doses of 1 dram twice daily. On February 6, 1932, the catheterized specimen was clear, and of a pH 5.8. On May 1, 1932, the right pelvic urine was acid to litmus and had a pH of 6.0.

The calculus was composed of uric acid and calcium carbonate. A postoperative *x*-ray was negative for any evidence of fragments.

Case III. J. W. L., white, aged forty-two years. The patient was first seen in June, 1919, at which time chronic prostatitis was present, and for which treatment was given at intervals for the subsequent four years. In 1923 dysuria with frequency developed and for the first time the patient reported the passage of four urinary calculi from the right kidney. In previous years, and at this study, his urine was found to be alkaline, with a definite infection in the right kidney pelvis. During the succeeding years, until September, 1928, numerous studies were made in an effort to determine the presence of tuberculosis; as well as an intermittent series of treatments for a persistent chronic prostatitis. During this time the bladder continued to get more and more intolerant, with a persistent alkaline urine and areas of marked ulceration. *X*-rays and pyelograms as early as February, 1923, had shown minute shadows in the lower calyx of each kidney. These were considered to be calculi, but as they measured but 6 × 4 mm. in size on the *x*-ray film, no operative interference was advised. Functional studies repeatedly showed the left kidney to have half the function of the right, and both diminished below normal. Three culture studies of the prostatic secretion remained sterile; while repeated studies for the tubercle bacillus (eleven in all) brought forth but one report of organisms suspected of being the tubercle bacillus. In September, 1928 an acute right ureteral blockage required an immediate ureterolithotomy in the upper third of the right ureter; recovery from which was prompt.

The finding of the one positive culture for the tubercle bacillus, plus his persistent and aggravated cystitis, caused the advice for him to go into the southwest, and while in New Mexico, during the summer of 1929, two operations were performed a month apart for an acute ureteral calculus blockage on the left side.

On his return, in the fall of 1929, *x*-ray examination revealed pocketed calculi in the lower calyx of the right kidney, and two small but suspicious shadows in the region of the left kidney pelvis. On June 4, 1930, a second acute calculus blockage of the right ureter necessitated a second ureterolithotomy to be performed on the right side in the upper third of the ureter. In November, 1930, a uroselectan study demonstrated the growth of the small shadows in both the right and left kidney pelves, but their size was no greater than could be expected to be passed in case dislodgement occurred. In fact, on numerous occasions, small calculi varying in size up to 5 mm. in diameter were spontaneously voided, and during this time the bladder capacity rarely exceeded 4 ounces. On November 28, 1930, a sizable soft stone was passed from the left ureter after a colic of a few hours' duration. During the ten months' interval between November, 1930, and September, 1931, enormous growth of stone took place and a uroselectan study of September, 1931, showed typical coral calculi in both the right and left renal pelves.

On November, 2, 1931, a fall from horseback was sustained and five days later severe colic with complete right ureteral blockage occurred, again associated with alarming clinical symptoms of an infectious character. A catheter was successfully passed by the stone and pelvic drainage obtained, and on November 16, 1931,

a third ureterolithotomy was performed followed by a pyelotomy, with removal of the large pelvic stone; then a nephrotomy into the lower calyx was done with the complete evacuation of the nest of calculi which had been observed there over a period of four years. (*X*-ray studies prior to this operation compared with the studies made two months before showed convincing evidence that the trauma sustained at the time of his fall had fractured the coral stone in his right kidney, a portion of which had caused the right ureteral blockage.)

Drainage was instituted at this operation to both the pyelotomy and the nephrotomy incisions. This drainage was sustained for a period of three weeks and the pelvis was irrigated daily, alternating between potassium permanganate followed by mercurochrome, and a 1 per cent phosphoric acid. It is of especial note that the phosphoric acid caused no renal discomfort, but regularly produced a sense of burning, not unbearable, in the bladder. The drainage tubes were removed at the end of three weeks and the fistula closed four days later. *X*-ray on December 18, 1931, the date of discharge from the hospital, proved the right kidney negative for calculi.

Since his hospital discharge, the patient has reported at ten day intervals for cystoscopic right ureteral catheterization and lavage. It is of importance to record that the first time in the period of eight or more years, the bladder has become tolerant of cystoscopy without sacral or spinal anesthesia. Its capacity has increased from 4 ounces to 14 ounces. The vesical lesions have retrogressed to a point where only an area possibly 1.5 × 2 cm. in size in the fundus of the bladder where the mucous membrane is still redundant, sodden and red. On January 12, 1931, urine collected from the right renal pelvis was brilliantly clear and weakly acid; while the bladder urine was still alkaline. Catheterization on January 28, 1932, showed the right kidney pelvic urine to have a pH of 5.8; while culture showed, on March 28, 1932, from the right side—an organism closely related to encapsulatus pneumonia and B. atrosepticus, and a pH 6.2; and from the left side (still stone bearing) a similar infection, and a pH 7.6.

The last stone removed from the right kidney was composed of calcium and magnesium phosphate, calcium oxylate, and calcium carbonate.

Case IV. C. S., male, aged twenty-nine years, admitted to the hospital February 26, 1932, complaining of attacks of pain in the left loin and left abdomen. These symptoms have been present at intervals over the past six years. *X*-ray showed a calculus in the upper third of the left ureter opposite the lower pole of the kidney. On March 2, 1932, an indwelling catheter was placed to the renal pelvis, following which a left ureterolithotomy was performed under a spinal anesthesia. The stone was found just below the ureteropelvic junction and the ureteral wall markedly thickened. Incision of the ureter failed to find the stone, and incision enlarged to pelvis through which the stone was found in the lower calyx and removed in toto. A No. 16 F. catheter was passed down the ureter and the ureter closed about it bringing it out through the posterior pelvic wall. A larger tube drain was placed in the pelvis through the same pelvic opening. Through the drainage tube the pelvis was irrigated daily with a 1 per cent solution of phosphoric acid. The tube was removed on the seventeenth postoperative day.

Two months later, on April 30, 1932, urine collected from the left renal pelvis was strongly acid to litmus, and gave a pH reading of 5.3.

On analysis the stone was found to consist of calcium carbonate and sodium urate.

Case V. S. D., female, aged fifty-seven years, was transferred from the Medical Service and found to have huge bilateral stag-horn calculi in both renal pelvis. She suffered particularly from pain in the right loin and seemed quite weak and lethargic. An indigocarmine test appeared from the right ureter in fourteen minutes, and from the left ureter in ten minutes, but with only fair concentration of the dye. Phenolsulphonephthalein test gave 20 per cent for the first hour; 10 per cent for the second hour. Blood urea nitrogen 24 mg. per 100 c.c.

Operation was performed on February 24, 1932, and a large stone successfully removed from the right kidney pelvis, by a pyelolithotomy, and a large drainage tube was placed through a nephrotomy incision. She received a daily irrigation of the renal pelvis with 1 per cent solution of phosphoric acid during twenty postoperative days, at the end of which time the tube was removed.

One week after this operation her blood urea nitrogen was 27 mg. per 100 c.c. On March 13, the blood urea nitrogen was 19 mg. per 100 c.c. On March 22, the blood urea nitrogen was 26 mg. per 100 c.c.

Her convalescence was uninterrupted, though she went home, on March 24, against our advice and before complete healing was accomplished. Subsequent observations have not been obtainable.

Analysis of the stone showed it to consist of calcium carbonate and triple phosphates.

Case vi. F. T., male, aged forty-four years, entered the hospital December 3, 1931, complaining of left loin pain. Sixteen years ago the patient suffered a similar attack which was relieved by a hypodermic, and there is no record of a stone being passed. Four months prior to admission he was seized with a severe left abdominal pain which was again relieved by a hypodermic of morphia, and a third attack of similar colic occurred five days before admission, continuing to date of same. *X*-ray study revealed a stone in the lower third of the left ureter, measuring 8 × 6 mm. The catheter obstructed at 8 cm. from the ureteral orifice. His urograms showed no evidence of pelvic back pressure. Nineteen days were consumed in various attempts at cystoscopic reduction and removal. This being unsuccessful, a ureterolithotomy was performed on December 23, 1931, and a solitary stone removed. A catheter drainage was placed to the pelvis through which, on one occasion only, a 1 per cent solution of phosphoric acid was instilled. This drain was removed on the fourth day, and on four occasions, postoperatively, the renal pelvis was irrigated at two-weekly intervals by cystoscopic ureteral catheterization.

The stone was not analyzed, but has the appearance of a calcium oxylate calculus.

Case vii. M. G., female, aged fifty-one years. This patient was admitted to the service of Dr. F. E. Keene on December 13, 1931. She entered the ward with a permanent right nephrostomy sinus. Her previous history recounts an appendectomy, a left nephrectomy for stone, an oophorectomy, a right nephrolithotomy, and later an operation for bladder ulcer and a permanent drainage for a recurrent calculus pyonephrosis of the remaining right kidney, which was performed July 6, 1930. She was in a critical condition from renal insufficiency, and her sinus tract was coated with phosphatic concretions. *X*-ray showed numerous irregular shadows extending down the sinus and involving the remains of a large pyonephrotic kidney. Her urinary drainage was strongly alkaline with a typical ammoniacal odor. After *x*-ray studies and various local measures had been tried, irrigations of the sinus tract with 1 per cent phosphoric acid solution was started on February 28, 1932. These were continued daily for five days without apparent discomfort, and with marked improvement in the wound's condition. The patient died suddenly of cardiac failure on the night of March 3, 1932.

Analysis of the calculus showed it to be of typical triple phosphates. This should have been a test condition in which to have obtained an ideal therapeutic result, and it is regrettable that sudden death defeated the outcome.

Case viii. H. H., male, aged forty-three years, admitted to the hospital March 2, 1932. History recounts a previous left pyelolithotomy for two renal calculi. The patient had suffered soreness and pain in the left side for the past three years. *X*-ray examination revealed two stone shadows in the left pelvis; while urograms showed one to be in the left renal pelvis, and the other in the lower major calyx.

Operation performed on March 9, 1932, demonstrated a stricture at the ureteropelvic junction, through which the incision was carried and two large stones were removed through this pyelotomy opening. A nephrotomy was performed through the lower major calyx and tube drainage brought into the pelvis. Pyelotomy incision was closed about a No. 12 rubber catheter inserted down the ureter and brought out through the nephrotomy wound with plastic reconstruction of the ureteropelvic junction. Daily irrigations with a 1 per cent solution of phosphoric acid were carried on through the drainage tube for seventeen days; the pH of the pelvic urine remaining at 6.0. The tube was removed on the seventeenth day.

Convalescence was uncomplicated. Culture of the urine showed bacillus coli communis.

Analysis of the stone revealed it to be of calcium carbonate and sodium urate.

Case ix. J. A., male, aged twenty-eight years, admitted to the hospital April 4, 1932, complaining of pain in the right side of the abdomen. There had been no previous operations. Study revealed a large calculus in the

right renal pelvis, which was moderately hydronephrotic.

An operation was performed on April 6, 1932, at which time a large stone was removed by a right pyelolithotomy, with a tube drainage to the renal pelvis. Irrigations of a 1 per cent solution of phosphoric acid were carried on through this tube every other day for three applications. The tube was removed on the sixth postoperative day.

Convalescence was uncomplicated.

Analysis of the stone showed it to be of calcium carbonate.

Case x. S. F., male, aged forty-three years, admitted to the hospital March 9, 1932, complaining of pain in the right renal region of six months' duration. Study revealed a stone of elongated shape filling a small intrarenal pelvis and plugging the ureteropelvic outlet.

Operation was performed on March 16, 1932, and the stone removed through a small pyelotomy incision. The only obstruction demonstrated was the adhesion of the ureter to the lower pole of the kidney, with moderate distortion of its course. A small rubber catheter was placed as a drain, through which a daily irrigation of 1 per cent phosphoric acid solution was carried on for the following five postoperative days.

Convalescence was rapid and uneventful. On May 5, 1932 his right pelvic urine was found to be clear with a pH of 6.0.

Analysis of the stone proved it to be of calcium carbonate, sodium urate and uric acid.

Case xi. H. B., male, aged twenty-eight years, admitted to the hospital April 1, 1932, complaining of right loin pain. This patient had been carefully studied before admission and all evidence pointed to the fact that he had a congenital absence of the left kidney, with a large stag-horn calculus in the pelvis and lower calyx of the solitary right kidney.

Operation was performed on April 12, 1932, and after a large pyelotomy incision was obtained, the calculus unfortunately broke on attempted removal. The portion remaining was impacted in the lower calyx. A nephrotomy was then performed over this point and the fragment was successfully removed. Reconstruction of the stone suggested that a third fragment was absent, though thorough search at operation and copious lavage of the pelvis failed to detect it. A large tube drain was placed through the nephrotomy wound to the pelvis and bleeding controlled by a mattress suture on either side of it. No repair of the pyelotomy incision was attempted.

Five days after operation, *x*-ray study revealed a fragment 7 mm. in diameter apparently lying in the pelvis 3 cm. from the end of the drainage tube. Before obtaining an analysis of the stone an attempt was made to dissolve this fragment by intermittent irrigations of 1 per cent solution of phosphoric acid. This was accomplished by passing a ureteral catheter through the lumen of the drainage tube into the renal pelvis. This catheter was connected through a Murphy drip with a transfusion burette, and for the subsequent fourteen days irrigation with 1 per cent solution of phosphoric acid was run through this at intervals of an hour on and an hour off. No discomfort was experienced except occasionally when the patient voided small quantities of urine there was a feeling of slight burning in the bladder and urethra. At the end of two weeks *x*-ray study failed to reveal any change in the stone's size, and a second small shadow was observed in the upper calyx. When comparing this plate with the one taken five days after operation (the latter having been taken in bed without preparation, and was not as clear as could be desired) showed that this second shadow was probably likewise present in the earlier plate too.

Failing of dissolution of the stone, an alligator forceps was passed through the drainage tube and the larger and lower stone successfully removed with the tube at one time. Since we felt somewhat uncertain of the smaller shadow in the upper calyx, the wound was allowed to heal and the patient voided a small stone without colic four days after the removal of the other stone. Analysis of these stones proved them to be of calcium carbonate and calcium oxylate.

SUMMARY

1. Phosphoric acid 1 per cent has a pH acidity of approximately 1.6. Its bacteriocidal value is based thereon.

2. Phosphoric acid 1 per cent is practically isotonic and is slightly less acid than the gastric acidity after a test meal.

3. In experimental dogs, renal pelves injected with 1, 3 and 5 per cent phosphoric

acid fail to show any destruction of pelvic lining epithelium, or damage to the renal papillae.

4. Eleven patients in whom renal pelvic lavage with 1 and 2 per cent phosphoric acid solution has been used, either through a postoperative drainage tube, through a ureteral catheter, or both, have not experienced discomfort or excessive renal pain. The bladder is less tolerant than the ureter or kidney pelvis, and the urethra is the least tolerant of all.

5. The renal pelvic urine in recorded cases has been re-studied and with one exception has been found to retain a normal acidity following this postoperative lavage.

6. This step in prophylactic treatment in cases of recurrent renal calculi has a rationale in both co-related conditions in the lower urinary tract and in bacteriological findings.

CONCLUSIONS

1. By bladder lavage with phosphoric acid postoperatively, alkalinization and phosphatic encrustations can be prevented.

2. The treatment of staphylococcic cystitis, encrusting cystitis, leucoplakia and allied conditions by this means is indicated.

3. The prevention of recurrent renal calculi of the phosphatic variety is being attempted with every indication of success.

4. The possible dissolution of small phosphatic calculi, or fragments left at operation, may be expected by the recognized action of such strengths of phosphoric acid in vitro, and the tolerance of such topical applications in vivo.

5. As a postoperative prophylactic measure against infection with the alkali producing organisms, it is herein proven safe and efficacious in kidney surgery and should therefore aid in the prevention of recurrent renal calculi of the phosphatic variety.

DISCUSSION

Dr. Oswald S. Lowsley: Nothing can possibly be more embarrassing than to have to operate on patients repeatedly for the same condition. It is happening to all of us. The prevention of urinary calculi is one of the most important things that we can consider. It has been our practice for some time to change the reaction of the urine in such patients by feeding them acid or alkaline, depending on the type of calculus found at operation. It is true that in a large stone, when one saws through it, such as a bladder stone, there may be several kinds of material, both alkaline and acid, in the substance of the stone, therefore one cannot in every case be sure that the recurrence of stone will be eliminated by changing the reaction of the urine, but we are quite convinced that in most cases a change in the reaction of the urine will prevent recurrence of stone, because they seem to have a certain specificity. I have mentioned many times a spectacular case in which we had to operate every six months for a period of time. About eight years has gone by now, and this lady, who had had seven operations, five of them by us, has not had a recurrence in eight years, due merely to changing the reaction of her urine. The patient does this herself by taking acid, in her case, and testing her urine with litmus paper. She has learned how to keep her urine acid without going into acidosis, into which we promptly put her when we instituted this treatment.

Dr. Randall has mentioned a most important thing in connection with this, and that is, you must have good drainage. There is no question about it. I remember several years ago Dr. McCarthy mentioned in the discussion of a paper here that his patients were relieved of calcium deposits on wounds by giving phosphoric acid, and so we have been giving it, and it seems to work as well as local irrigation.

I think it is proper in this connection to remember that one must eliminate all possible sources of focal infection. The brilliant work done at the Mayo Clinic in isolating bacteria from the tooth and actually producing stone in the dog's kidneys by injecting these bacteria must make us be alive to the fact that there may be specificity of bacteria, and therefore it is part of our routine always to eliminate every possible source of infection, in the mouth, tonsils, teeth, sinuses, and so on.

Dr. J. A. Killian: For a number of years we have been interested in the problem of urinary calculi from the standpoint of the relationship

of their formation to metabolic reactions in the body, and up to date we have no information of positive value, either concerning their etiology, or methods of preventing their recurrence. However, our work has brought to light a few suggestions which we consider of some practical value. With regard to the change in the reaction of the urine, I think it is important to bear in mind that not only bacteria have the ability to transform urea or amides into ammonia; normal kidney tissue also has that property, and according to the work of Bliss, it is probably most potent of all the tissues in the body in its reaction of de-amidization. Moreover, this ability to de-amidize on the part of the kidney tissue may vary with renal function, either in one direction or the other. At the present time we cannot say whether a diminution of renal function, so far as nitrogen excretion is concerned, is associated with a corresponding impairment of de-amidization. The increase in alkalinity in the urine, due to the ammonia formation, may not be entirely the property of bacteria; it may be due to disturbance in renal function. It is true that vitamin A deficiency changes the character of the epithelium so that it is possible for crystals to become fixed or adherent to the epithelial lining, and the use of cod liver oil to supply the necessary vitamin A is wise, not only on account of its supplying large quantities of vitamin A, but also because it supplies vitamin D, whose principal function is concerned with the fixation of calcium and phosphorus in the body, and of course, preventing the loss of calcium or phosphorus from the body in the excreta. In our advice to urologists to be handed on to patients, what we attempt to do is to avoid changes in the reaction of the urine (we are speaking now entirely of phosphate calculi), changes in the urine in the direction of increased alkalinity, and also to avoid an excess of calcium, magnesium and phosphate which may be excreted in the urine. I think by careful restriction of the diet we can do more to regulate the reaction of the urine than we can by the administration of acids by mouth, with the possible exception of phosphoric acid.

The first thing we do is to avoid the giving of bulky meals, because this is followed by an alkaline tide in the urine. This is greatest following the morning meal, less following the noon or afternoon meal, and it varies directly with the quantity of HCl secreted by the stomach, and the quantity of HCl secreted by the stomach varies again directly with the bulk of the meal. About 1919 Blathewick published a series of observations on the influence of fruits and vegetables on the reaction of the urine, and that list is valuable in the selection of fruits and vegetables which will increase the alkalinity of the urine. In choosing foods as a source of calcium and phosphorus, we bear in mind the fact that all observers who have studied the question of the utilization of calcium and phosphorus by the body, as for instance, Sherman, Mendel, Shohl, etc., have brought out the fact that when calcium and phosphorus are utilized by the body most satisfactorily under the influence of vitamin D, they are utilized or stored in about the same proportion in which they occur in milk; usually two parts of calcium to one part of phosphorus. In regulating our calcium and phosphorus in the diet, we attempt to observe that ratio.

Another important thing is this: it has been recently shown that probably the phosphate which occurs in the urine is not all filtered from the blood. It may be formed by the action of kidney tissue on hydrolyzable phosphates in the blood. We therefore avoid giving a large quantity of carbohydrate with any one meal because with a large supply of carbohydrate we have an increase in the hydrolyzable phosphates in the blood which furnishes available material for an increase of phosphate in the urine.

Dr. Joseph F. McCarthy: Dr. Killian and I have conjointly made it our rule to have the most precise quantitative and qualitative estimations made of every stone removed; Dr. Killian then attempts to regulate the patient's metabolism as nearly as possible from the biochemical standpoint. For quite a number of years we have been using acidulated fluids in the bladder cases mentioned by Dr. Randall with considerable success. I feel we are much indebted to Dr. Randall for carrying out that idea to its logical conclusion, the renal pelvis. Personally, I think there are three factors: (1) the factor of obstruction, the primary factor; (2) the biochemical, and (3) the factor of infection.

Dr. Victor Cox Pedersen: The element of infection has been spoken of throughout the evening as to teeth and tonsils, but not materially as to the intestines. I think we do

not do our duty by any of these cases unless we investigate what is going on in the intestinal canal. Over and over again we find a very active disorder, usually in the form of the failure of balance of the bacteria that belong there, the B. coli group making up from 65 to 95 per cent, associated with some of the ordinary pus-producing organisms. Here we have a case in point. A man sixty-three years old, with no teeth, tonsils out, suddenly develops hematuria. The phenolsulphonephthalein test is normal; the urine is normal except for blood and numerous B. coli, staphylococci and enterococci. The intestinal tract shows very active fermentation of carbohydrate with butyric acid fermentation associated with it, and some putrefaction. All that is necessary in that man is obstruction somewhere in his urine-secretory apparatus to produce pus there, either as a general infection of the mucous membrane or a single focus of pus in the kidney, or multiple foci, or the precipitation of salts in the formation of stone. By paying attention to his diet and using urinary antiseptics we have so far brought that man far along in the line of convalescence. If we can evolve for him the right kind of diet, that man should never again have any trouble from his urinary system, but it was a hotbed of infection. I believe we are erring when we do not go into the intestine for one of the sources of trouble in all cases of kidney trouble.

Dr. Randall (*Closing*): The subject of stone is certainly a baffling one, and no theory is going to solve the question in its entirety; the causes are too diversified. My remarks have been limited to phosphatic stone. I do not think that dietary regime as a treatment or prevention is going to do anything of great benefit. It has been tried so many times and in so many different ways. But that it is a factor in stone formation cannot be denied. I have been trying to read into stones the picture which most of us have of the necessity of finding an obstruction, and two weeks ago, in removing a kidney stone and being unable to demonstrate the reason for its being there, I had the opportunity of apologizing for my theory before the class. I expounded on the idea of the dietary question as an answer in this patient. The chap was under spinal anesthesia, and I was talking not to him, but to the class, of the likelihood of dietary reasons being in his case the cause of stone formation, and the patient spoke up and said: "You certainly hit it on the head." He ran a restaurant, and ate at the most irregular hours and irregular food, and he said: "Moreover, my sister has had a stone removed from her kidney, and my father died of a kidney stone." His was not a phosphatic type of stone, but that there are factors, such as diet, which enter into the problem, must not be denied.

This study has three reasons for its presentation: First, it begins to show that the renal pelvis has been a *noli me tangere* for too long a time, and I believe we will learn to do more in the way of local handling of pelvic troubles in the future. Secondly, I feel that the use of phosphoric acid in the way outlined is a safe step in preventive treatment, and a prophylactic against secondary phosphatic stone formation. Thirdly, it may be curative in those cases where alkaline forming organisms already dominate the field and are causing recurrent precipitation of phosphate concretions.

PRESENT STATUS OF SURGICAL TREATMENT IN PULMONARY TUBERCULOSIS*

POL. N. CORYLLOS, M.D.

NEW YORK CITY

IN a paper published in 1822, Sir James Carson, this early pioneer in the treatment of tuberculosis, said; "It has long been my opinion that if ever this disease is to be cured, and it is an event of which I am by no means disposed to despair, it must be accomplished by mechanical means."

This prophecy has been, partially at least, fulfilled. We at present possess efficient surgical means by which mechanical collapse of the diseased lung and cure of tuberculosis can be accomplished. Pneumothorax, thoracoplasty, apicolysis, partial thoracoplastic collapse, multiple intercostal neurectomy, pneumonostomy and possibly pneumonectomy are the means by which remarkable results have been so far obtained.

If I might use a metaphor I would say that the possession of arms and ammunition is not sufficient for the winning of a war. The art of using them efficiently is of greater importance than their mere possession. The science of ballistics is far more important than the discovery of explosives and without an exact knowledge of their proper use our weapons may be more of a menace than an aid.

When dealing with the surgical treatment of pulmonary tuberculosis, and perhaps with thoracic surgery as a whole we surgeons must understand that the pioneer period is past. We enter the ballistic period of this method, if I may use this expression, which is the thorough knowledge of physiology and pathologic physiology of the two principal functions we have to deal with, namely, respiration and circulation and more especially, as thorough a knowledge as possible of the pathology and clinical evolution of pulmonary tuberculosis. The heroic period of rib-cutting and surgical gymnastics has likewise passed. Thoracic surgery today is a highly specialized branch in which the surgeon must possess a great deal of theoretical and special technical knowledge, and furthermore get the habit of working hand in hand with the medical man, the bronchoscopist, the roentgenologist and the pathologist; each individual problem should be discussed in common, so that the indication for operation can be reached and even the kind of operation determined. The surgeon is no longer permitted to say to the medical man, "If you cannot do anything for that patient, let me try surgery upon him." Moreover it is my belief that if we wish to have our patients benefited by our progress in thoracic surgery we should first gain their confidence and more especially the confidence of our colleagues in medicine. The surgeons operating in large tuberculosis hospitals know well how difficult it is to convince the patients to be operated upon and the poor moral effect upon them of an unsuccessful attempt; on the contrary it becomes easy to sell them the idea of operation after a series of operative successes. On the other hand the medical men and the phthisiologists can afford no longer to ignore the resources of modern thoracic surgery, even in apparently desperate cases which seem beyond surgical help. Therefore the cooperation of those practicing thoracic surgery tempered with a degree of boldness, and of broadminded and progressive phthisiologists is the ideal

* From the Thoracic Surgery Departments of Metropolitan and Seaview Hospitals, N. Y. Read at the Convention of the N. V. A. Sanitorium, Saranac Lake, N. Y.

scheme for promoting and developing surgical therapy in tuberculosis. If we wish to advance the efficiency of surgical treatment of tuberculosis by extending its indications and increasing its effectiveness, phthisiologists must become more surgical minded and thoracic surgeons must learn more and more about the physiology and pathology of the chest organs.

With these ideas in mind I am not going to deal with surgical technicalities, in so far as I can avoid them. Nor do I intend saturating this paper with literature with which the reader is familiar. I shall try to present the results of the experience of our medicosurgical chest group, obtained at an active center of about 2000 beds comprising the tuberculous services of Metropolitan and Seaview Hospitals, in which 8 to 15 major operations are performed every week, and in which several hundred cases with pneumothorax are constantly and carefully followed. My topic will be more especially the scope and indications of modern surgery in pulmonary tuberculosis.

IMPORTANCE OF CLASSIFICATION

It is evident that discussion of this subject cannot be placed upon solid foundations unless we first agree upon a comprehensive classification of tuberculosis, both pathological and clinical. Talking about surgical treatment of tuberculosis is, today, something as vague as discussing the surgical treatment of tumors in general. The differences between benign and malignant tumors are by no means greater than the differences between various forms of pulmonary tuberculosis.

I agree with Tendeloo that a clean-cut classification of pulmonary tuberculosis is impossible. However, having had the privilege of working for the past year in close cooperation with Dr. George G. Ornstein and his staff I am strongly impressed by the usefulness of the classification elaborated by him and Drs. Ulmar and Dittler. Their division of pulmonary tuberculosis into four forms—caseous pneumonic, exudative, exudative productive and chronic productive, is in my experience a proven clinical reality; it offers the great advantage of a solid foundation upon which our operative indications can be determined, and upon which our results, successes or failures can be better understood.

The caseous pneumonic form of tuberculosis corresponds to the ulcerocaseous or fibrotic forms of different authors. Caseation, expulsion of the sloughed-out material and formation of cavities are its characteristics. Fever and toxic symptoms generally subside with the elimination of sloughed-out pulmonary tissue, and the general condition of the patient improves. But the cavities remain open, sputum is persistently positive and spontaneous cure under medical treatment is exceptional, if possible. This is what I might call the one and only surgical form of tuberculosis in which surgical treatment is indicated.

The exudative form, which is an acute type of temporary duration, represents an intense allergic reaction in a hypersensitized lung due to a small superimposed tuberculosis infection of a patient hypersensitive to the tubercle bacillus or its products. Massive infiltrations are often present; its beginning might be clinically and radiographically identical with the onset of the caseous pneumonic form. Annular shadows are frequently present in the radiograms, and are often impossible to differentiate from real cavities, although the scarcity of physical signs is in favor of the former. Only the evolution of the disease can solve this diagnostic problem which is of paramount importance for the choice of treatment. In fact, a few months or oftentimes a few weeks of complete rest will suffice to clear up these signs and cause the annular shadows to disappear. The fundamental differences between caseous pneumonic and exudative forms is that in the latter there is no necrosis and sloughing out of pulmonary tissue but only an infiltration which heals by resolution. Surgery has not and must not have anything to do with this form. There is no doubt in my

mind that the bulk of "successes" after phrenicectomies refer to this form and that the "miraculous cures," as we shall see later, have been obtained not because of, but in spite of, the operation. The same holds for pneumothorax or any other form of collapse therapy which cannot logically be indicated for a consolidated and non-collapsable lung.

The third form is the *exudative productive* in which after absorption and healing of the inflammatory process, which may be very slow, strands of scar tissue are left behind. But there is no tendency to softening or cavity formation and consequently no indication for collapse therapy.

The fourth form is the *chronic proliferate or chronic productive*, corresponding to the acinonodosal form of Aschoff. It is the result of small superinfecting doses in a relatively non-allergic tissue, essentially chronic, accompanied by very few symptoms and is little influenced by any form of treatment, except in some cases in which small cavities are present.

It is obvious that for these last two forms there is no indication for surgical treatment, except when caseous pneumonic tuberculosis is associated with them; consequently surgical cures reported as having been obtained in these two forms of tuberculosis cannot be given serious consideration because surgery cannot influence their course.

The foregoing considerations justify the contention that only a comprehensive classification will enable us to understand one another when we discuss indications and results of surgical treatment of pulmonary tuberculosis and that reports of operative cases in which the form of tuberculosis is not clearly indicated cannot be considered of any scientific value.

Surgical treatment of tuberculosis should thus be limited exclusively to caseous pneumonic forms and more especially to what Ornstein, Ulmar and Dittler designate as the "end results" of this form, that is the honeycombed lung or that with cavitations the size and localization of which may vary. Indications and methods vary according to the degree and location of the lesions, the resistance of the patient and the presence or not of pleural complications. Serous fluid or even purulent tuberculous fluid developed spontaneously or following artificial pneumothorax does not greatly influence operative indications; mixed infection, on the contrary, and especially when septic or anaerobic infection with or without internal or external fistulae is present, does influence the treatment. Because of their importance the surgical treatment of these pleural complications will be touched upon separately at the end of this paper.

Surgical treatment in caseous pneumonic tuberculosis aims at the anatomical collapse of pulmonary cavities and is successful only when this result is obtained. The methods of collapse therapy are: artificial pneumothorax, phrenicectomy, intrapleural or extrapleural pneumolysis with or without "plumb" and thoracoplasty, paravertebral partial, total or enlarged. Other methods, more radical aiming at the suppression of the diseased area and more in the domain of the future than of the present, are pneumonostomy and pneumonectomy, that is opening and draining of intractable cavities or surgical removal of the diseased portion of the tuberculous lung.

PNEUMOTHORAX

Pneumothorax produces collapse of the lung by suppressing the normally negative intrapleural pressure. The lung, a perfectly elastic organ, collapses when air is introduced in the pleural cavity by the same mechanism as when an opening is made in the thoracic wall. It does not collapse because it is "compressed" by the air introduced into the pleural cavity but because it is no longer forced to expand by the negative intrapleural pressure. In fact, the lung always tends to collapse and will do so unless it is forced to do otherwise. So that when we talk of "compression" of the lung in artificial pneumothorax we

merely forget that within an hour or so, after positive intrapleural pressure is artificially produced, the intrapleural pressure again becomes negative because of the active interchange of gasses through the pleura. Only in the cases with very thickened pleura can positive pressure be maintained for a longer time. It is not the same, of course, with spontaneous pneumothorax in which tension pneumothorax is often present due to the one-way valve mechanism of the pleuropulmonary communications. In these cases air accumulates in the pleural cavity and its pressure can become equal to the pressure developed in cough, that is up to +60 or +80 mm. Hg, which is a tremendous positive pressure when compared to the −6 mm. Hg of mean normal pressure. However even in these cases, when the internal fistula is sealed up even for a short while, the pressure very rapidly falls, parallel with the fall of partial pressure of O_2 which from 20 per cent drops to 5, 4, 3, 2, 1 per cent, and even less. Studies of the O_2 and CO_2 percentage in the gases in pneumothorax carried on at Metropolitan Hospital with the cooperation of Drs. Kontrowitz and Levine, and at the Surgical Research College with Dr. Birnbaum, have convinced me that prolonged "active compression of the lung" by artificial pneumothorax is an *ignus fatum*, a physiological impossibility. The logical conclusion of these facts is that frequent refillings, even with moderate pressures, are far more efficient in collapsing the cavities and maintaining the collapse than sporadic ones even with high positive pressures.

With these restrictions, I admit that artificial pneumothorax is the most efficient means at our disposal for collapsing pulmonary cavitations; this however depends upon other factors which may prevent collapse. Adhesions of the lung to the thoracic wall (or more exactly of the visceral to the parietal pleura), or very thickened visceral pleura, or central location of the cavities may render impossible a satisfactory selective collapse. In these cases, if after a month or two, good selective collapse is not obtained it is useless and even dangerous to continue the refillings: it is useless because the absence of effective collaps does not favor cure; dangerous because if the sputum remains positive a spread of the disease to the other lung or even to the already collapsed lung is always a possibility. Furthermore, spontaneous pneumothorax can occur at any time in the course of an artificial pneumothorax, which is always a serious and often fatal complication even in patients so far apparently in good condition. The use of *oleothorax* with or without gomenol oil for the purpose of thickening the pleura and preventing spontaneous pneumothorax has not, thus far, given us satisfactory results. Therefore I believe that it is useless and dangerous routinely to prolong pneumothorax treatment under these conditions and lose that valuable period during which other and more efficient methods can still be effectively used. It is time I, believe, to react against indiscriminate use of this otherwise most useful therapeutic procedure.

Our group of workers believe that pneumothorax should be avoided in the very early periods of acute tuberculosis for the following reasons: (1) because early diagnosis between exudative and caseous pneumonic forms is often very difficult; (2) because even with the caseous pneumonic type in its early stages it is impossible to compress a lung which is still consolidated and in which cavities as such are not yet present; (3) it is especially in these early forms that spontaneous pneumothorax most frequently complicates artificial pneumothorax.

Furthermore we believe that in chronic cases of caseous pneumonic tuberculosis indications of pneumothorax should take into consideration the degree of destruction of the parenchyma of the affected lung. We come more and more to the conclusion that when the degree of destruction of the lung parenchyma is such that there can be no reasonable hope for effective reexpansion, an early thoracoplasty may be

the treatment of choice. In fact, in such cases, where pneumothorax has been maintained for several years, the healed lung is often so thoroughly organized that when the air is allowed to be absorbed, mediastinum, heart and trachea are displaced to the affected side and dyspnea due to the traction upon the heart and to vicarious emphysema of the other lung develops. In these cases we are obliged either to maintain the pneumothorax indefinitely or to perform a thoracoplasty. The question we are studying at present is whether in these cases a definite thoracoplastic collapse, which will save the patient often several years of inactivity and protect him from complications which are always possible, is not the best solution of the medical and economical problems involved.

To summarize, we can state that artificial pneumothorax is indicated only in caseous pneumonic forms and only when effective collapse can be obtained. Otherwise pneumothorax should be completed or replaced by other surgical measures.

PHRENICECTOMY

Paralysis of the diaphragm by surgical procedures upon the phrenic nerve is produced with certainty only by avulsion of the nerve. Block by alcohol injection, by crushing or simply by sectioning the phrenic nerve, aimed at the production of temporary paralysis of the diaphragm is inefficient in at least 50 per cent of the cases. The presence of one or more accessory phrenic nerves, as well shown by Felix, is not always affected by these procedures unless very skillfully performed, so that paralysis of the diaphragm does not occur and the operation is useless.

Phrenicectomy produces immobilization of the diaphragm in an elevated position, loss of its muscular tonus and muscular atrophy. The degree of elevation depends, naturally, upon the difference between intrathoracic and intra-abdominal pressures. When the lung is healthy, as when phrenicectomy is performed for intractable hiccough, very slight elevation of the diaphragm occurs. On the contrary in tuberculosis in which the lung shows fibrotic retraction, the diaphragm will rise considerably, being aspirated into the thoracic cavity because of the lowering of intrathoracic pressure due to the shrinkage of the lung; this occurs by the same mechanism as in massive atelectasis, and, as in this condition, not only the diaphragm but also the trachea, the heart and even the thoracic wall are displaced towards the affected side. The proof of this is given by the well-known fact that oftentimes in cases of fibrotic or atelectatic shrinkage of the lung we find the diaphragm, without phrenicectomy, more elevated than it is in exudative or productive forms after phrenicectomy. For these reasons it is an open problem whether fibrosis of the tuberculous lung and cure of the disease is the result or the cause of the rising of the diaphragm. At any rate as it is inadmissible that an inert membrane such as the denervated diaphragm can play any active role in its rise we must look elsewhere to justify the possible usefulness of this operation. The proponents of phrenicectomy contend that collapse of the cavities and cure are produced by compression, relaxation and immobilization of the lung, and by modifications in the physiologic action of cough.

Let us see how effective these factors are.

There is no doubt that phrenicectomy produces but a slight decrease in the capacity of the chest, equal to a pneumothorax not exceeding 200 to 300 c.c. of air. It is obvious that this cannot produce by any means an effective degree of pulmonary collapse. As for the so-called "relaxation" I confess that I cannot understand its mechanism. Slight decrease in the size of the lung and slight decrease of its elastic recoil cannot produce collapse of large cavities in the midst of a portion of lung parenchyma which is more resistant than the healthy parts of this organ. We know that often we cannot obtain an effective collapse of cavities even with successful pneumothorax in which 1000 to 1500 c.c.

of air are maintained in the chest, or with thoracoplasty, when they are central and covered by a considerable amount of healthy tissue. How then can we admit that a paralysis of the diaphragm, equivalent to a small pneumothorax, can bring about the collapse of an apical or even a lower lobe cavity? The only method by which closure of a cavity could be produced would be kinking of the "drainage bronchus of the cavity" and absorption of the air contained therein, as Alexander, Laurell and myself have shown. Phrenicectomy has never been able, clinically or experimentally, to produce a degree of collapse of the healthy lung sufficient to cause atelectasis even in the portions of the lung which are in direct contact with the diaphragm, as 400 or 500 c.c. of fluid in the chest will do. For these reasons "relaxation," if possible, is of negligible importance. It is rather one of those more or less metaphysical expressions which unfortunately only too often have found their way into pulmonary pathologic physiology and which show how little clinicians often care about physiology.

Similarly immobilization of the lung produced by phrenicectomy is much less important than is generally believed. There are at present in the literature a number of cases in which double phrenicectomies had been performed at one sitting for hiccough. Experimental cases of bilateral phrenicectomy are legion. In neither of these instances have asphyctic phenomena been noticed. This shows that the intercostal and accessory respiratory muscles can easily replace the paralyzed diaphragm. Furthermore Duchenne de Boulogne showed, over fifty years ago, that very rapidly after phrenicectomy the activity of the lower intercostal muscle increased to such a degree that even the inspiratory expansion of the costal borders which is due to the action of the diaphragm and which has temporarily decreased after phrenicectomy returns to normal after a short time. This transient and relative immobilization of the lung may explain to some extent the temporary improvement often noticed after phrenicectomies; so that the most we can say in that respect, is that phrenicectomy cannot produce immobilization of the lung unless by other procedures the intercostal muscles have already been paralyzed as after multiple neurectomy or thoracoplasty; phrenicectomy *alone* cannot permanently immobilize the lung.

In the same way, the modifications of cough action due to phrenicectomy are so variable in character and degree as to have no definite importance. We have seen in our cases and in those reported in the literature that some patients expectorate more, some less, some easier than before, some with greater difficulty and in some no change has been noticed. From the foregoing considerations it appears that the therapeutic influence of phrenicectomy upon the course of caseous pneumonic tuberculosis, the only type in which it is indicated, is almost if not entirely nil. In 150 cases of caseous pneumonic tuberculosis operated at our center by different surgeons, and examined from six months to five years after operation by Dr. Ulmar and myself, we have not been able to discover a single case of permanent cure due to phrenicectomy. Therefore I believe that the so-called numerous "cures" reported by tuberculosis centers in which this operation is performed in an indiscriminate way and as a routine operation are hasty reports dealing with cases which showed slight and only temporary improvement; or they concern cases of exudative forms of tuberculosis in which cure has occurred by itself as in cases I showed at the beginning. Does this mean that we should exclude this operation from our surgical treatment? To this question I answer, yes, if we count on it alone to cure our patients; precious time is lost in waiting for results, exactly as with an inefficient pneumothorax; in both instances, other and more effective procedures should be added, and this before the proper time to act is past. On the contrary, phrenicectomy when used in conjunction with other operations such as thoracoplasty is useful provided that we do not expect from it more

than it can give. Some will probably object that a distinction should be made between apical and basal lesions, and between a thin and thick walled cavity. I do not believe this, and at least our results do not permit us to accept this distinction. Among the cases I referred to, there is an imposing number of thin-walled apical and basal lesions, in which no definite collapse of the cavities was produced and no permanent cure was obtained.

The results of phrenic exeresis in hemoptysis are equally problematic. Hemoptysis is so capricious in its onset, duration and severity, and often stops so suddenly, that it is difficult to formulate a definite statement upon the efficiency of phrenicectomy in it.

PNEUMOLYSIS, INTRAPLEURAL OR EXTRAPLEURAL

Intrapleural. In cases of pneumothorax, in which collapse is prevented by adhesions, Jacobaeus, Unferricht, Kremer, Matison, Maurer and others, have devised and perfected a method of intrapleural section of the adhesions, guided by a special endoscopic instrument, similar to the cystoscope, known as the thoracoscope. Sections of the adhesions can be done with the electric cautery or by high-frequency coagulating and cutting electrodes. There is no doubt that in well-selected cases where the adhesions are thin, avascular and sufficiently long so as not to expose the patient to the danger of hemorrhage or section through the diseased lung parenchyma and consequent production of pleuropulmonary fistulae with spontaneous pneumothorax and empyema, this method is useful. In 12 of our cases a perfect collapse was obtained after section of adhesions, and were followed by clinical improvement with negative sputum, in spite of the development of aseptic fluid in the chest in one of them. I therefore subscribe to what Sauerbruch has said, namely, that this procedure, in carefully selected cases and when skillfully performed, may give valuable results.

Another method of intrapleural pneumolysis consists in the section and ligature of the adhesions after thoracotomy. The consensus of opinion is that this is often a dangerous procedure in tuberculous patients. Thoracotomy for tumor of the lung is harmless, because in these cases the pleura is healthy; on the contrary in cases with tuberculous pleura often after thoracotomy fistulae are formed leading to tuberculous empyemas with superimposed infection by pyogenic organisms.

Extrapleural: More efficient and, I believe, more promising are the procedures designated under the name of extrapleural pneumolyses, especially when applied to apical lesions where pneumothorax has not been able to collapse the adherent apex.

The objective of extrapleural pneumolysis, or more exactly of apicolysis, is the selective extrapleural collapse of the diseased apical lesion alone, whereas the healthy part of the lung is left untouched. Three methods thus far have been proposed for surgical collapse of apical cavities.

1. *Extrapleural Apicolysis.* This procedure consists in stripping the parietal pleura of the apex from the chest wall and filling the space with fat, homogenous or autogenous, or with a pendunculated muscular flap or better with the paste of Baer called by the German authors "plombe"; this is a mixture of paraffin fusible at 48°C., with 1.5 per cent of neutral bismuth carbonate and 1.5 per cent vioform. This operation is performed under local anesthesia by posterior paravertebral incision or anterior under the clavicle. If the intercostal space is not wide enough to permit the introduction of a finger, a 2 inch length of the second rib is resected. Posteriorly the third rib should always be resected.

2. *Scalenectomy.* The second method is scalenectomy with resection of the first two or three ribs, by anterior approach. It was devised by Jay Coffey in this country and Lawers in France. The incision is made above the clavicle; after

section of the clavicular portion of the sternomastoid muscle, both scalene muscles, anterior and posterior, are sectioned and the first rib is resected for its entire length. Thus the apical pleural dome is definitely deprived of its suspensory systems, so that after being stripped from the chest wall it has no tendency to re-expand. In this procedure, which is carried out under local anesthesia there is no necessity of any filling or paste; furthermore there is no danger either of tearing the pleura or of injuring any of the important vessels or nerves which lie on the apical dome, as is possible in the previous method.

3. The third procedure, advocated by Maurer, Rolland and Proust in France, consists of a *complete resection or even disarticulation of the first two or three ribs* by a paravertebral approach. It is therefore more of a partial upper thoracoplasty than an apicolysis.

I have performed 16 apicolyses by the first method without any postoperative mortality or morbidity. In 3 the cavity left after stripping of the pleura was filled with pedunculated muscular flaps and gauze packing; in the remaining cases Baer's "plombe" was used. The oldest patient was sixty years of age, the youngest was sixteen. All have markedly improved and 30 per cent are now bacilli free. Three patients had bilateral lesions. In one a girl eighteen years of age apicolysis was performed on the right side, and a week later pneumothorax was induced on the left side followed by a good collapse of this lung, and marked improvement of the general condition. In one a bilateral plombe has been done, and in the third the other side will be performed later.

The possible complications of this method are: (1) suppuration due to the paste and its elimination; (2) perforation of the roof of the pulmonary cavity and penetration of the paste down in to it; (3) forcing of adhesions by the weight of the paste and migration of it lower in the chest. The second and the third complications are exceptional, and they expose the patient to a serious danger. I never have had any of these accidents with this method. On the contrary, slow expulsion of the paste from the chest, so that it gradually bulges under the skin, forming a tumor the size of which varies from that of a walnut to a hen's egg frequently occurred in my cases, necessitating the extraction of the protruding paste under local anesthesia. Serious suppuration never occurred, although in 3 cases I had fistulae which had persisted during several months. I think that this method constitutes a real progress in surgical treatment of tuberculosis because of its benign nature, its efficiency in one-third of the cases and especially because of its possibilities in bilateral cases. Its principal indications are: (1) cavities or lesions of the apex, with the rest of the lung free, when these lesions are located above the third rib anteriorly and when previous pneumothorax did not collapse them; (2) in bilateral apical lesions; (3) in apical lesions in one lung with more advanced lesions in the contralateral lung, but which can be collapsed by pneumothorax or even by thoracoplasty. In these cases, apicolysis is certainly a better method than bilateral pneumothorax, or phrenicectomy on the side of the apical lesion and pneumothorax in the other. The fourth, which according to Sauerbruch, Felix and Niessen is its principal indication, is in cases in which thoracoplasty has not produced a complete collapse of the apical lesions. Conversely, if apicolysis has not completely collapsed the apical lesions there is no contraindication whatever in later performing a thoracoplasty. I do not believe that apicolysis is a procedure as efficient as an upper thoracoplasty, but it has the advantage over this operation of being far less serious.

MULTIPLE INTERCOSTAL NEURECTOMY

This operation, devised by Alexander, consists in the resection of the intercostal nerves of the diseased side. It is a technically easy operation, and generally harmless. Combined with phrenicectomy it assures a good immobilization of the chest. It is

unable however to produce any kind of adequate collapse, therefore its field is limited to the cases in which nothing more can be done, or in which immobilization alone is considered sufficient.

THORACOPLASTY

The last procedure for surgical collapse of the lung is paravertebral thoracoplasty performed according to the technique of Sauerbruch. It consists in resection of paravertebral segments of ribs, from the first to the eleventh inclusive. As Gravesen has shown, when segments of 10 to 15 cm. of each rib have been resected, the best results are obtained when this resection affects the paravertebral segments of the ribs and even includes the tips of the transverse processes. The degree of collapse depends upon the lengths of the resected segments. No sufficient collapse can be obtained unless the first rib is resected. In fact the ribs are suspended from the first through the intercostal muscles and the first from the cervical transverse apophyses through the scalene muscles. In well-performed thoracoplasties the three diameters of the chest are affected; the anteroposterior because of the decrease of the length of the costal arcs, the frontal and vertical because of the dropping of the ribs.

This operation can be performed in one stage. It is more conservative, however, to perform it in two or more stages. I think that in thoracoplasty, as in thyroidectomy for toxic goiter, the surgeon should adjust the operation to the resistance of the patient. When the pulse becomes rapid and the blood pressure falls the operation should be ended. It is better to do much less than a little more; and it certainly is better to cure the patient in several stages than to kill him in one. During the last decade, following these principles the mortality of this operation has dropped from 75 per cent as it was with the large operations performed by Friedrich to about 14 to 10 per cent and even less.

The general indications for thoracoplasty are fairly definite at present; unilateral caseous pneumonic cases, with positive sputum, afebrile, in relatively good condition, and in which a pneumothorax was impossible or ineffective; tendency to retraction of the diseased lung with displacement of the trachea, heart and diaphragm to the diseased side; weight stationary or increasing and rather moderate expectoration; these are the clinical symptoms which characterize good surgical risks. Patients running a slight fever, presenting moderate spreads in the collateral lung, and showing some degree of toxemia, constitute, according to the intensity of these signs, only fair or even bad surgical risks. In our services we consider fit for thoracoplasty all cases of unilateral caseous pneumonic tuberculosis after the caseous content of the lesions has sloughed out. Another factor of great importance which should be taken into consideration in the selection of cases is the resistance of the patient, which is not always in direct relation to its clinical appearance. Unfortunately we do not as yet possess a clinical method comparable to the "functional test of the kidney," for measuring the resistance of the patient. It seems *a priori* that the determination of oxygen utilization capacity of the patient at rest and exercise and the changes in the heart output could give us valuable information on the resistance of the patient and consequently of his ability to resist the operation. We are working on this question at the present time. In the meantime we consider that hemoglobin above 70 per cent, pulse below 100, little or only moderate increase in respiratory rate after a standard exercise, integrity of the kidneys and of the gastrointestinal tract are the requirements for the operability of the patient. On the other hand, tuberculous laryngitis, slight gastrointestinal tuberculosis, streaking and even hemoptyses do not constitute contraindications to operation.

The average results of thoracoplasty as compiled by the cases so far published in the literatures can be expressed as follows in round figures:

Without operation out of 100 patients with caseous pneumonic tuberculosis in which pneumothorax was not effective, 50 per cent died within a year, 30 per cent more within two years, 10 per cent more within three years and only 10 per cent survived over four years (Nissen). According to Barnes and Barnes, in 1465 cases with cavitations, the average span of life was 15.8 months, and 80 per cent died within the first year. Out of 100 similar patients submitted to thoracoplasty (Nissen) 50 were completely cured; that is, within one to two years after operation they were able to perform a full day's work without fever, cough or expectoration and were permanantly bacilli free. Twenty were alive ten years after operation, greatly improved, the most of the time bacilli free, without fever and able to perform some work. Fifteen to 20 died from the operation and in 10 the course of the disease had not been influenced by the operation. In other words of 100 patients doomed without thoracoplasty to certain death, obliged in the meantime to spend their life in sanatoria, and constituting a real danger for the community, 60 to 70 were able to return to active life and become an asset instead of a liability to society.

In this postoperative mortality are included all deaths occurring within three months after the operation when related to it. Ten to 20 per cent mortality may appear considerable. But if we consider that 100 cases represent 200 or 300 operations, upon patients the condition of whom is rather precarious, these figures become more acceptable. Furthermore I think that the surgeon must not try to correct his statistics by decreasing the extent of the operation. Surgeons who resect 1–3 cm. of ribs have no mortality, but they have no cures either. When we decide to operate upon a tuberculous patient we must perform a real thoracoplasty, that is the resected segments of the eleven ribs must have a total length of 160 to 180 cm. with at least 7 cm. of the first rib. Otherwise the operation is useless. Incomplete thoracoplasties discredit the operation more than 10 to 20 per cent mortality. That is probably why some authors, as Fishberg in his book, have stated that they never saw a tuberculous patient cured by a thoracoplasty. It is in tuberculosis as in cancer. Radical operation presents a higher mortality but also can show definite cures.

In my statistics of 72 cases I had a 16 per cent mortality. But on the other hand, 76 per cent of my patients became and remained bacilli free.

The principal causes of postoperative mortality are: the so-called aspiration pneumonias and bronchopneumonias, heart failures, mediastinal flutter, postoperative shock and infection of the wound. Wound infection can be avoided to a great extent with well-regulated team work and faultlessly functioning operating rooms. Occurrence of serious shock can be diminished by good selection of patients, adequate preoperative care, well-regulated operative technique, and skillfully conducted cardiotonic treatment, hydration of the patient and transfusions. Here again the close cooperation of the surgeon with the phthisiologist are of the greatest importance. Postoperative pulmonary complications and heart failure constitute the two most important causes of postoperative morbidity and mortality. I place them together because I believe that they have the same cause, which is acute or subacute but prolonged anoxemia. In fact according to the ideas I have expressed elsewhere with Dr. Birnbaum, and in favor of which we presented clinical and experimental evidence, I firmly believe that these postoperative complications are due to bronchial obstructions to the impairment of bronchial drainage, the production of atelectasis and the resulting marked impairment of the respiratory and circulatory functions. As a matter of fact we operate upon patients lying on the healthy side so that during

operation purulent exudate coming from the diseased lung necessarily drains into the bronchi of the other lobes and is gradually carried down into the smaller bronchi. The amount of sputum thus drained during the operation varies according to the amount of the expectoration of the patient and to the degree of surgical collapse produced in the diseased lung during the operation. If the patient is not well under anesthesia so that during operation he becomes restless and makes crying gestures he may be induced to take deep respirations and the infected fluid is carried farther down into the smaller bronchi. Thus, bronchial obstructions and atelectasis, massive or lobular, can start on the operating table or shortly after as in the cases reported by Berry. This is not all. During anesthesia the patient aspirates a considerable amount of mucus and saliva, coming from the mouth and rhinopharynx, which always contains aerobic, and anaerobic microorganisms and more particularly pneumococci group iv. Lemon and Higgins have shown that by simply dripping into the mouth of an anesthestized dog 20 per cent India ink solution, this is found in the small bronchi within forty minutes. Myerson has shown by bronchoscopic examination of patients undergoing tonsillectomy that blood is present in the bronchi in 90 per cent. Thus the three factors necessary for production of pulmonary complications, namely, bronchial stasis, impairment of bronchial drainage and increased viscosity of bronchial exudate, due to the pneumococcus, are present. Many cases of patchy or massive pneumococcic atelectasis rapidly change to bronchopneumonia or lobar pneumonia. In all our cases which presented such complications the sputum, carefully checked, always contained pneumococcus group iv. These complications lead to anoxemia, to shallow rapid breathing and to "acapnia" (washing out of CO_2). Thus a vicious circle is created. Acapnia will further increase anoxemia, because of the decrease of the physiological stimulant of the respiratory center (CO_2) and because of the Bohr effect, that is the higher saturation of hemoglobin with oxygen in the presence of lower tension of CO_2 and the formation of oxyhemoglobin in which oxygen holds fast to the hemoglobin and is not liberated in the tissues. If this condition is not rapidly relieved disorganization of the respiratory center will occur. The best way of relieving this condition is persistent inhalation of O_2-CO_2 7 to 10 per cent. This mixture is administered by intranasal catheter or better by placing the patient in an oxygen tent for twenty-four to forty-eight hours whenever symptoms of anoxemia-acapnia develop. In cases of atelectasis immediate bronchoscopic liberation of the bronchi is advised, if the obstruction is not rapidly relieved by moving the patient from side to side. Transfusion is of a great help because it increases the amount of circulating oxyhemoglobin and thus immediately corrects anoxemia.

The heart and the vasomotor centers, on the other hand, are no less sensitive to anoxemia than the respiratory center, so that fall of the blood pressure and dilation of the heart rapidly occur. I believe that the so-called heart failures are nothing else but acute dilatations brought about by anoxemic crisis. The practical conclusion to draw from the foregoing considerations is that it would be desirable to elaborate an operative method by which the following requirements could be fulfilled: (1) keep the patient during operation under quiet anesthesia by maintaining a constant pulmonary ventilation; (2) cut off as much as possible any communication between the upper and lower respiratory tract; (3) which is of the greatest importance, remove from the bronchi, before, during and at the end of the operation the exudate accummulated in them or drained into them from the diseased lung.

For these reasons, I actually use[1] general anesthesia with gas-oxygen and a small amount of ether, administered through a specially devised "intratracheal" catheter. This intratracheal catheter is introduced

[1] *Anesth. & Anal.*, 11: 138, (May-June) 1932.

into the trachea under local anesthesia and the pharynx tightly packed with gauze. This procedure, when skillfully done, can be accomplished without the slightest inconvenience for the patient. The results so far obtained in 150 thoracoplastic operations performed upon 72 patients, have allowed us to eliminate pulmonary complications, and gave a surprising decrease in postoperative morbidity and in spread of the disease to the healthy lung.

In closing this study of surgical treatment of pulmonary tuberculosis, I shall mention two procedures, namely, pneumonostomy and pneumonectomy.

Pneumonostomy is the opening and draining of tuberculous cavities through the chest wall as in putrid abcesses of the lung. Tuberculous cavities have been accidentally or deliberately opened and drained. Dr. Lilienthal reported 3 similar cases, and in a few cases good results have been obtained. In our service however we were not successful with this procedure.

Pneumonectomy is the resection of the tuberculous lung, as in bronchiectasis. MacEwen had a striking result in one case, in which he performed, in several stages, an almost complete resection of one lung. This procedure is indicated in cases of tuberculosis in which bronchiectasis has secondarily developed, and more particularly when this occurs after otherwise successful thoracoplastic collapse.

PLEURAL COMPLICATIONS

When serous fluid is present or purulent exudate containing only tubercle bacilli, unless it is threatening the life of the patient because of its amount, the best method of treatment is to avoid any repeated tappings which often are followed by external fistulae and secondary infection of the exudate by pyogenic germs. The treatment of choice of tuberculous empyema is thoracoplastic collapse of the pleural cavity.

The same is not the case when, following spontaneous pneumothorax or fistula of the thoracic wall, mixed infection results. According to the degree of infection, oleothorax with gomenol oil or injection of dyes may be sufficient for checking the infection. If these do not prove to be successful then the cavity should be washed and drained, preferably by the closed method. As soon as the acute infection is over, if the lung does nor or should not be allowed to expand, a thoracoplasty should be performed in as many stages as the condition of the patient indicates. In cases of putrid empyema immediate drainage must be performed. The prognosis in septic cases is very serious and in putrid empyema almost always fatal.

Early diagnosis of spontaneous pneumothorax is therefore important. Generally the clinical symptoms are sufficient for the establishment of the diagnosis, and injection of gentian violet in the pleural cavity allows the disclosure of the bronchial fistula. But it is not always so. Sometimes it is difficult to arrive at a definite diagnosis of the presence of a pleuropulmonary communication. It might be of interest, therefore, to mention a method developed in our services for the diagnosis of these cases.[1] It consists in the analysis of the gaseous contents of the pleural cavity. Whenever the oxygen is less than 2 per cent and CO_2 more than 7 per cent spontaneous pneumothorax with persistent bronchial fistula can be excluded. The same method allows the measurement of air contained in the chest, and by successive readings during refillings, the determination of the absorbing capacity of the pleural serosa for O_2 and CO_2.

CONCLUSIONS

1. By surgical treatment of tuberculosis we must understand a number of operative procedures which are able to immobilize, collapse and compress the lung, in order to collapse the cavities and help cure the patient.

2. The adoption of a standard classification of the disease is necessary, so that indications, results and statistics may be comparable and of real scientific value.

[1] *Am. Rev. Tuber.*, 26, (Aug.) 1932.

3. Collapse therapy is indicated only in the caseous form of tuberculosis, and only after the period of consolidation is over when the necrotic material has been sloughed out.

4. The widespread idea, expressed by Dumarest under the epigramatic sentence "pneumothorax is the treatment of the acute period of tuberculosis and thoracoplasty of its chronic phase" is not completely correct in the first part. In the very acute period of tuberculosis any collapse therapy is useless, because of the impossibility of collapsing a consolidated lung and because exudative tuberculosis generally heals by itself; it is dangerous because of the frequency of the occurrence of spontaneous pneumothorax.

5. Pneumothorax if it does not produce selective collapse is useless and harmful and should be replaced by more efficient collapse therapy.

6. Phrenicectomy is unable by itself to produce a definite cure of tuberculous cavities. It is useless in the other forms of tuberculosis. Associated with other collapse methods it may be of real help.

7. Intrapleural pneumolysis by the method of Jacobaeus, in well-selected cases and skillfully performed, can give good results.

8. Extrapleural apicolysis with or without compression of the apex by foreign bodies as packing or "plumbe" is a method which is especially indicated in bilateral cases.

9. Thoracoplasty is the most efficient method for permanent and definite collapse of the lung. It is, however, a major operation, requiring a faultless technique, a careful selection of cases, adequate preoperative preparation and painstaking previous estimation of the resistance of the patient; ether anesthesia is harmless, but should be administered by such methods as to allow a complete separation of upper and lower respiratory tract and permit the suction of the bronchial exudate. Intratracheal anesthesia fulfills these requirements. The most important postoperative complications are cardiopulmonary complications generally following bronchial or bronchiolar obstruction and the resulting atelectasis and anoxemia.

10. The treatment of pleural complications varies according to the nature of the exudate; it should be conservative, in aseptic tuberculous exudates. Thoracoplasty is the treatment of choice. Injection of gomenol oil or dyes is to be tried in moderately infected empyemas; drainage should be installed in mixed infections and more especially in anaerobic empyemas later followed by thoracoplasty.

11. Thoracic surgery in tuberculosis requires the close cooperation of the thoracic surgeon with the phthsiologist, not only before but also after operations; tuberculosis patients should no more be considered as medical or as surgical patients, but as medicosurgical cases requiring continuous medicosurgical supervision, study and treatment.

Pulmonary tuberculosis can be successfully treated "by mechanical means" as Carson prophesied. This part of the problem is solved. What remains to be done is to perfect our technique and to devise some means by which mortality will be decreased and operative indications enlarged.

In closing I wish to quote the wise words of Fichel. We should not forget, says this author, in studying the treatment of cavities, that:

> Time is an important factor in the treatment of pulmonary tuberculosis and that all indications are strictly limited by time and hold good only for the short duration of the respective stage of the disease. After all, treatment of tuberculosis is the treatment of tuberculous cavities. Opportunities are quickly missed and chances for more conservative measures easily overlooked until finally the most radical procedures have to be resorted to. In going over the histories and films of chronic patients one can read many tales of "what might have been" and cannot help thinking that there is perhaps a period, however short, in the life of every tuberculous patient when the closure of his cavities by the appropriate method may turn the scales in his favor.

FRACTURE OF SESAMOID BONES*

A REPORT OF TWO CASES

JACOB SAGEL, M.D.

MINNEAPOLIS, MINN.

FRACTURE of the sesamoid bones is a relatively rare condition and very little on this subject is reported in the literature. The cases reported are usually fractures of the sesamoid bones about the great toe, but these rarely occur without fracture of other bones of the foot. I have seen no case reports of fracture of the fabella, the sesamoid bone located in the head of the lateral tendon of the gastrocnemius muscle. This report consists of 2 cases; one a fracture of the fabella and the other a fracture of the external sesamoid of the great toe unassociated with fracture of any other bones of the foot.

FIG. 1. Intercondylar fracture of left femur. Note fracture of fabella (arrow) with separation into two large fragments and several smaller ones. Deformity of head of tibia and fibula is due to previous fracture.

FIG. 2. Same case, twenty-seven months later. Union of two large fragments of fabella has occurred.

CASE 1. A carpenter, sixty-seven years old, injured his left knee October 2, 1929, sustaining an intercondylar fracture of the left femur and a stellate fracture of the fabella, an inconstant sesamoid bone in the external tendon of the gastrocnemius muscle at the level of the popliteal space. To ascertain the exact mode of occurrence of the fabellar fracture, I questioned the patient as to the details of the injury. He was reaching for a small board which lay behind a pile of plaster boards, each 4 by 12 feet, when the pile fell

* From the Departments of Radiology of the University of Minnesota, the University Hospital, and the Minneapolis General Hospital, Minneapolis, Minnesota.

Presented before the Minnesota Radiological Society, Feb. 13, 1932.

against him. He was thrown upon a beam which was lying across a roll of insulating felt so that his left knee was caught between them in a partly flexed position. Following the injury he remained in the hospital for three weeks. At present he has almost no trouble in walking.

Fig. 3. Congenital bifid division of fibular sesamoid of great toe. Note smooth, rounded contours of two parts, which are in close apposition, and transverse line of division, with no evidence of union. Compare with Figure 4.

The first examination (Fig. 1) shows the intercondylar fracture of the left femur and the stellate fracture of the fabella. Multiple irregular fragments of the fabella, which are somewhat separated, are shown. The appearance is characteristic of a fracture of a sesamoid bone and does not at all resemble the appearance of a bifid sesamoid which has smooth rounded edges with the two halves in close apposition (see Fig. 3). Figure 2 shows the appearance on January 15, 1932, at which time union of the larger fragments had occurred.

Case II. A man, aged forty, was injured in an auto accident, sustaining a crushing fracture of the external sesamoid of the left great toe (see Fig. 4). One large fragment and several smaller ones are shown. It is of interest that none of the other bones of the foot was fractured. The foot was caught between the floor of the car and the door thus crushed the external sesamoid of the great toe by direct trauma. Follow-up examination on this patient could not be obtained.

The chief diagnostic importance of this fracture is to differentiate it from a congenital division of the sesamoid bones, which is not uncommon (Fig. 3). Division of the tibial sesamoid of the great toe is more common than that of the fibular sesamoid. Burman and Lapidus[1] report 6 cases of division of the fibular sesamoid and 72 cases of division of the tibial sesamoid of the great toe in a series of 1000 cases. A. H. Bizarro,[2] in his review of the literature, noted only 6 cases of fracture of the fibular sesamoid of the great toe. The case reported here, a fracture of the fibular sesamoid of the great toe, without fracture of any other bones of the foot, is very rare. In congenital division of the sesamoid bones the two parts have smooth contours, generally show a transverse line of division, and are usually in close apposition, whereas the fragments of a fractured sesamoid usually have irregular contours and may be widely separated. Burman and Lapidus state that callus unites the ends of a fractured sesamoid bone which then definitely distinguishes it from a congenitally divided one. Union occurred in our case of fractured fabella (see Fig. 2). A comparison of all of the plates shown demonstrates well the difference between these two conditions

[1] *Arch. Surg.*, 22: 936, 1931.
[2] *Ann. Surg.*, 74: 783, 1921.

so that no difficulty should be encountered in making the diagnosis.

The rarity of fractured sesamoid bones should make one hesitate somewhat in diagnosing this condition unless the definite findings shown here are present.

Fig. 4. Fracture of fibular sesamoid of left great toe. One large fragment and several smaller ones, all with irregular edges are shown. Note absence of fracture in other bones of foot. Compare with Figure 3.

THE WRIGHT METHOD OF TREATING LEG ULCERS*

H. R. SHANDS, M.D.

JACKSON, MISS.

DURING my internship in the Charity Hospital in New Orleans, twenty-eight years ago, a valuable lesson was learned concerning the healing of chronic leg ulcers. An old street sweeper had been coming to the out patient clinic two or three times a week for twenty years to have a varicose leg ulcer treated and dressed. The custom then was to change the attending resident every six months, so during this time he had been treated by at least forty doctors and no doubt had almost as many different kinds of treatment applied. The ulcer remained unhealed. At this time he was knocked down by a runaway horse and sustained a fracture of the thigh. It was necessary to put him to bed for ten or twelve weeks to treat the fracture; the ulcer healed while he was in bed with no special medication.

The common treatment for this condition thirty years ago was to apply various kinds of salves and medicines, dress the leg every few days and give mixed treatment. In the mind of the attending surgeon the patient was regarded as a syphilitic until proven innocent. The presence or absence of syphilis has little effect on the healing of the ordinary leg ulcer. Syphilis as an etiological factor enters into the causation of chronic leg ulcers in a remarkably small percentage of cases.

The use of various antiseptics has had little effect on chronic leg ulcers. The failure to heal is due to venous stasis and poor return circulation. This fact is generally conceded now.

Leg ulcers are most certainly not as commonly encountered now as they were in the first decade of this century. There has been in the past twenty years considerable advance in the treatment. Beck's adhesive plaster strapping of the ulcer was a valuable contribution. The practice of surgical removal of the varicose veins, and more recently of injecting irritating solutions to block the veins, has caused many chronic cases to heal. The use of the supporting boot of Unna's paste is a very useful method of treatment.

Notwithstanding these advances a goodly number of cases of chronic leg ulcer are still to be found in the out patient departments of our large hospitals. This is a condition that occurs much more commonly among the poor. In the rural districts more cases are present than the average physician would think. These people, on account of poverty and discouragement from past futile treatment, do not come to the doctor. The sum total of their suffering and disability is still great.

On several occasions during the past few years Mr. Dickson Wright of St. Mary's Hospital, London, has described a method of treatment which is most efficacious. He read a paper on this subject before the British Medical Association in Winnipeg, in August 1930, and I had an opportunity to see him demonstrate his method during the following month. Since then I have had occasion to treat 23 cases of leg ulcer by his method. The principle underlying Mr. Wright's method of treatment is that of compressing the leg with elastic adhesive plaster, thereby overcoming the passive congestion due to the diseased and dilated veins.

Over one hundred years ago Thomas Baynton, a surgeon of Bristol, made the following observation: "This disease is due to the unfavorable situation of the parts which are placed at a remote distance from the fountain of life and heat, and are obliged to return the venous

* Read at the meeting of The Southern Surgical Association, White Sulphur Springs, W. Va., Dec. 10, 1931.

blood and lymph to the heart under peculiarly unfavorable and disadvantageous circumstances." Mr. Wright states:

A simple experiment proves his contention: A needle connected to a glass tube 8 feet long is inserted into any varicose vein, the blood rises instantly to the level of the ears; if he now lifts a heavy weight in both hands the upper level is now far above his head and the venous pressure even greater than the arterial. Put the hydraulics right and the ulcer will take care of itself is the gist of the method. The edema is harmful and the varicose circulation useless, so they should be squeezed out of existence by an adequate and uniform compression.

The technique of Mr. Wright's method of treatment is as follows: When the patient first presents himself with a chronic leg ulcer, if there are visible varicose veins, one of these rather high up in the leg is injected with 5 per cent sodium morrhuate solution. I have used this solution and quinine and urethane and find the sodium morrhuate is more effective. Immediately after the injection of a varicose vein an elastic adhesive plaster bandage is wound snugly around the leg from the foot or ankle to just below the knee.

In the first week or so of the treatment if the ulcer is foul with a very free discharge, it will probably be wise to change this dressing twice a week. Later the plaster is usually left on for a week and in the late stage of the treatment, often longer. If the ulcer is painful, there may be a little more pain for the first few hours after the application of the plaster, however, by next morning the pain is all relieved and does not return during the course of the treatment. Within ten days or two weeks a large ulcer, which has resisted previous treatment for years, shows great evidence of healing and the granulations, which have been indolent and unhealthy, become pink and firm and show every evidence of a healthy surface with rapid epithelization at the edges. One vein is injected at each subsequent application of the plaster. The injection of the veins is not at all necessary to cause the healing of the ulcer under the plaster, but this is a convenient time to inject the veins to prevent a recurrence of the ulcer. This method is simplicity itself and can be applied by any physician.

In his paper before the British Medical Association Mr. Wright reported 324 cases treated with 321 healed. Two discontinued treatment for some cause and one patient died of abdominal cancer before finishing treatment. Mr. Wright further states:

The advantages of the compression are as follows: (1) It abolishes the varicose circulation. (2) It diminishes the oedema, in some cases reducing the volume of the leg by 4 or 5 pints. (3) It thus reduces the girth of the leg in oedematous cases, and thereby reduces the width of the ulcer by the same amount before any healing takes place at all. (4) It approximates the edges of the ulcer. (5) It protects new epithelium and delicate granulations from dressing trauma. The discharge lifts the sticking plaster away from the ulcer, and renders removal painless and harmless to the epithelium and granulations. (6) It presses down and softens the raised margins of an indurated ulcer, so rendering it flat instead of excavated. (7) It provides a "pansement specifique." (8) It abolishes pain in the majority of cases. (9) It permits full functional activity, and patients who work and take exercise are cured more quickly than those in bed. (10) It saves the expense of dressings and lotions. (11) It requires no particular skill. (12) In early ulcers (up to six months' duration) there are numerous invisible islets of epithelium buried in the granulations; pressure brings these to the surface and they quickly cover the ulcer. Frequently an ulcer of the size of the palm of the hand, if of short duration, will heal within seven days. (13) It cleans the ulcer more quickly than any antiseptic method, and the foetor rapidly disappears. (14) It brings to the surface varicose veins which were deeply buried in oedema, thus rendering injections possible which otherwise could not be attempted. (15) It gives a supple scar, which loses its adherence to the underlying bones.

He further states:

Six years' experience with this treatment enables me to promise the patient: (1) To

cure any ulcer, no matter of how long standing, or to what extent adherent to bone, at the rate of one square inch per week. (2) To relieve all pain. (3) To allow full work and exercise. (4) To eliminate the possibility of recurrence in nearly every case.

To the uninitiated in this method of treatment these claims must sound most extravagant. The experience which I have had with 23 cases leads me to accept these claims with practically no mental reservations. In addition to being a specific treatment for varicose leg ulcers I have found the treatment very efficacious in other leg ulcers. During the past winter a colored girl, aged nineteen, was referred to me with a leg ulcer 2 inches by 3 inches in diameter, on the left leg. This ulcer had been present for nine years. On examination it was immediately discovered that she was somewhat anemic and jaundiced and in reply to questions she gave a history of at times having cramps in her abdomen and some joint pains. This, of course, suggested sickle-cell anemia as the cause of the ulcer. Blood examination confirmed this suspicion. It was explained to her that certain cases of sickle-cell anemia could be cured by splenectomy. In her case an incision was made for splenectomy. The spleen was, however, found atrophied so that it was no larger than two joints of the thumb. These cases with extreme atrophy of the spleen apparently are not benefited by splenectomy. The surgeon being aware of this fact and also due to the fact that she was extremely tall, 6 feet, with a very long chest, so that the spleen was placed very high above the edge of the ribs, it was judged there would be some slight danger in removing this spleen with the probability of no benefit, so the abdomen was closed without splenectomy. She was kept in bed for two or three weeks for the wound to heal. During this time there was only slight evidence of healing of the leg ulcer although she was quiet in bed. After she was up and about, the plaster was applied in the usual manner and the ulcer healed rapidly and firmly in five weeks. In this case there was no evidence at all of venous stasis, in the ordinary acceptance of the term. This girl, although she was 6 feet tall, weighed only 107 pounds and the circumference of the calf of her leg was only 9½ inches.

Mr. Wright has found that this method of treatment does well with almost every kind of ulcer, such as bed sores, perforative ulcers or denuded areas after amputation of the breast.

Sir Almoth Wright has made certain experiments studying the reasons for the benefit in ulcers not due to varicose veins. In an untreated ulcer a cover slide is laid on the ulcer and becomes coated with discharge and then is laid wet side down on a petri dish and cultured. The result shows colonies everywhere: B. coli, staphylococcus, streptococcus, B. pyocyaneus, etc. In a treated ulcer the same is done. Colonies now appear not under the cover glass at all but only where the fluid has dried beyond the edges of the cover glass. The inspissation kills the leucocytes or bacteriophage or whatever it is and the organisms live.

This elastic bandage is really practically an ACE bandage with zinc oxide adhesive applied to one side of it. After the plaster is applied there is a free discharge of serum through the mesh of the plaster. Certainly some antiseptic or chemical action takes place on the bacteria on the surface of the ulcer which has a most favorable action on the healing process. The wound is dressed with its own discharge, the "pansement specifique" of Besredka.

In the cases of large ulcers the time of healing can be considerably reduced by skin grafts. After the plaster has been applied for two or three weeks the granulating surface becomes pink and healthy with the skin edge on the lever with the granulation. Almost any kind of properly applied skin graft will take on this surface, with the patient up and about and the plaster placed over the ulcer and the skin graft, in the usual manner. We have made this a simple office procedure, removing under local anesthesia pieces of whole thickness skin ½ inch in diameter, from the patient's thigh and placing them around

over the ulcer. Within ten days they have firmly taken and new areas of granulation develop from them. Mr. Wright commonly uses a method of darning strips of skin under the granulation surface with a needle. This method of grafting is very useful and was described by Dr. William L. Keller of Washington.[1] Mr. Wright has recently fired pieces of skin into the ulcer with an air pistol and had them take.

The greatest advantage of this method of treatment is that it is just as efficacious in the leg ulcer following a postoperative or postinfection phlebitis as it is in the ordinary varicose ulcer. The method of application is exactly the same. It is surprising how rapidly these ulcers will heal under the elastic adhesive plaster.

J. B., colored male, aged sixty, first seen November 4, 1930.

Twenty years ago he had typhoid fever followed by a phlebitis, the leg swelling and giving him a great deal of trouble since then. Thirty-three years ago he had syphilis. Nine years ago he developed an ulcer on the left leg.

When first examined the calf of the right leg measured 16 inches and that of the left leg 19 inches. The left leg was greatly swollen and there was a large ulcerated area on the lower external surface of this leg and a smaller one on the inner surface. The large ulcer was 3½ inches by 2 inches.

The plaster was applied in the usual manner. After the edema was squeezed out by the plaster a few varicose veins were discovered and injected at one week intervals. This ulcer was completely healed by the middle of January, 1931. No specific treatment was given as his Wassermann reaction was negative. On discharge the circumference of the left leg was 15 inches where it had been 19 inches at the beginning of treatment. This ulcer had resisted other forms of treatment for nine years and was completely healed under this treatment in nine weeks.

Mr. Wright has reached the conclusions that the average rate of healing of the ulcer under the elastic bandage is one square inch per week. Some of the recent ulcers heal much more rapidly.

We had one case in the person of a colored cook whose ulcer had been present only eighteen months. His ulcer was so painful that he frequently had to call a doctor at night to give him morphine, and often he had to use two crutches in walking. He came to our office with one crutch and a walking stick to assist him in walking and he was suffering greatly from the leg. He had suffered with phlebitis two years before and the ulcer had been present for eighteen months. Soon after the development of the ulcer some physician gave him *x*-ray treatment. The pain and discomfort from the ulcer were so great that we feared he might have an *x*-ray burn. After applying the plaster the pain was relieved in sixteen hours, and the ulcer entirely healed in two weeks. In this case there were areas of skin at various places over the ulcer which could not be seen until after the plaster was applied and removed at the end of a week.

Mr. Wright reports one remarkable case:

James W. age fifty-two, thirty years ago in the Boer war developed typhoid fever complicated by femoral thrombosis and an ulcer developed immediately after he got about; since then this has never healed but has slowly grown to encircle the leg and measures 31 square inches in area although his total hospitalisation over the thirty years amounted to 7½ years. Every treatment including skin grafting has been carried out, amputation had been repeatedly refused and the Pension Committee had awarded him a lifelong pension of two pounds a week. A most conservative estimate of the cost of this ulcer to the patient, and state gave a figure of over five thousand pounds! With 21 weeks of the treatment outlined above he was completely cured and during the whole period of treatment followed the most unfavorable of occupations, viz. that of a house painter, earning four to five pounds per week. He stated that during the treatment he had less pain than at any time in the course of the disease. There were no varicose veins at all in this case so the patient is now wearing an elastic support to prevent recurrence.

He states: "This treatment is just as diagnostic as 606 in syphilis, if an ulcer does not heal it is either cancer, syphilis or an *x*-ray burn, if a treatment is diagnostic, it is specific, effective."

After fifteen months' experience with this method of treating chronic leg ulcers I am of the firm opinion that Mr. Wright's method of treatment is a very valuable contribution, and his claims not overstated.

[1] *Ann. Surg.*, June 1930.

DIFFICULT HERNIAS

SURGICAL TREATMENT WITH SPECIAL REFERENCE TO A MODIFIED METHOD OF OBTAINING LIVING FASCIAL SUTURES*

JOSEPH E. FULD, M.D.

NEW YORK CITY

THE advent of living fascial sutures is a distinct advance in the operative treatment of certain forms of hernias. changed after transplantation, the hernial defect becomes permanently closed and the hernia remains cured.

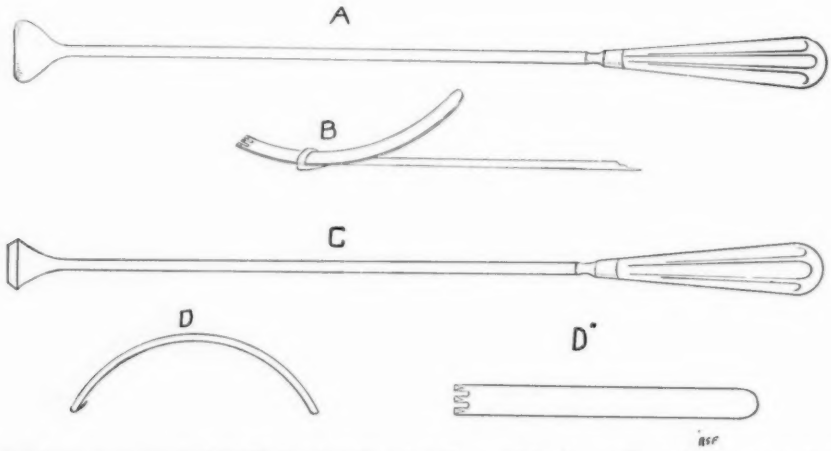


FIG. 1. A. Fuld's fascia separator. B. Fuld's fascia threader (in position). C. Grace's fascia stripper. D. 1. Fuld's fascia threader (side view). 2. Fuld's fascia threader (top view).

Before the introduction of living fascial sutures by Gallie and Le Mesurier in 1923, there was considerable confusion as to what was the best operation for large ventral, recurrent, direct and inguinal hernias.

When other than living suture material is employed in hernia repair, the postoperative success is dependent upon the process of healing by delicate scar tissue. The scar is not strong and slowly stretches when subjected to strain. The success of the living fascial suture method is based on the fact that the structures of real strength, the musculo-aponeurotic borders of the ring are left strong enough to withstand considerable strain. Further factors in the success of fascial suturing are strength and permanence of the sutures used. These sutures neither stretch nor contract. Due to the well-known fact that fascia lata transplanted continues to live practically un-

The principle of using the living fascial sutures differs from the use of other sutures in that other sutures draw the conjoined tendon and Poupart's ligament together, or draw together the margin of the ring in a ventral hernia with the hope of securing edge-to-edge apposition and union, while the living fascial suture is woven or laced into the space between the conjoined tendon and Poupart's ligament, thereby closing the deficiency of Hesselbach's triangle in a direct hernia, or by the process of basket-like weaving similar to the manner in which one would close the hole in darning a sock. The closure does not depend upon drawing together the weakened and atrophied edges under tension, but by filling in the intervening space with a filigree formed of the fascial inlay the ventral hernia may be closed.

*Read before the Clinical Society of the Correction Hospital, New York City, Oct. 27, 1932.

When a defect is present and support is required, as is usually the case in difficult hernias, no other material can be used with such satisfactory results. The Gallie operation, which is admittedly superior to older operative methods for the cure of hernia, is, however, frequently refused by the patients because of the long scar which results when fascia is taken from the thigh. The Gallie operation is also accompanied by an increased period of disability, due to operation on the thigh or by infection of the thigh wound in some cases.

These objections have been largely overcome through the use of the fascial stripper devised by R. V. Grace. Because of the density of the connective tissue, considerable technical difficulty is frequently encountered in removing the fascial tissue with this stripper.

My modification of the technique suggested by Grace consists of using two additional instruments, which I have devised. (Fig. 1.) I am now able to remove the fascia more easily and more quickly with the Grace stripper. In a series of 35 cases in the past 6 months, I have been much impressed with the ease of technique when using these two additional instruments.

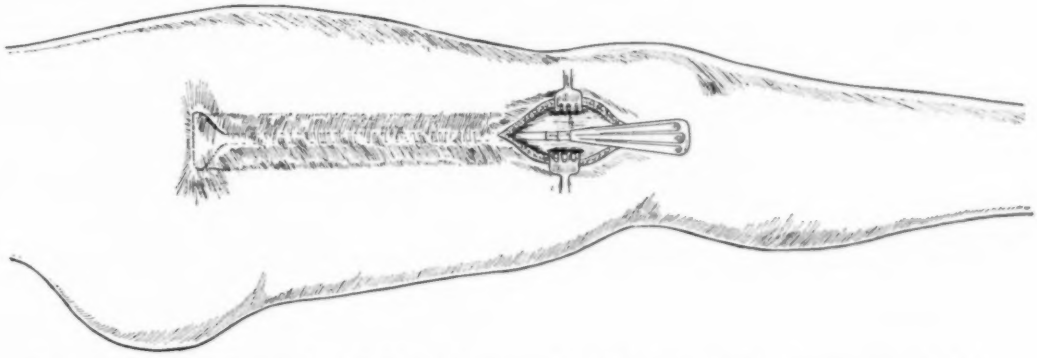


Fig. 2. First step. Separation of skin and connective tissue from fascia (instrument in situ).

TECHNIQUE

1. Make a 2 inch longitudinal incision on the outer aspect of the thigh beginning at the level of the upper border of the patella. (I prefer a longitudinal incision because the direction of the fibers of the fascia is more easily seen.)

2. Carry the incision to the fascia and dissect the skin and subcutaneous tissue laterally about an inch on each side of the incision, exposing clean fascia to view. Continue the separation at the upper angle of the wound for about 3 inches by blunt finger dissection.

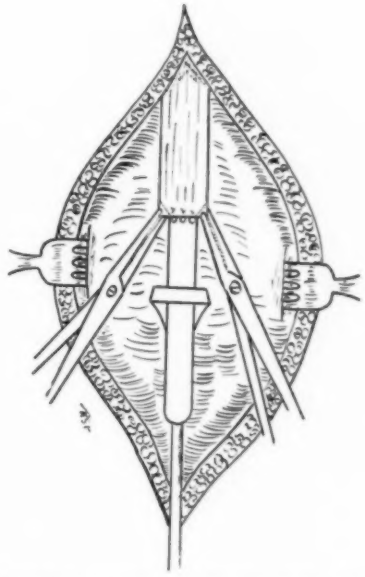


Fig. 3. Showing corners of fascia strip to be cut off to permit easy threading through stripper. It is very important to depress gripper end of fascial threader as it passes through stripper.

3. Separate the subcutaneous tissue from the strip of fascia which is to be removed. This is accomplished with my "fascial separator" which is constructed as a large size fascia stripper but differs from it by having the cutting end replaced by a

solid piece, with a blunt non-cutting end. This instrument is held at an angle of 20 degrees with the thigh, and is pushed upward to the full length of the thigh along the direction of the fibers of the fascia in the plane of cleavage between the latter and the subcutaneous tissue. (Fig. 2.)

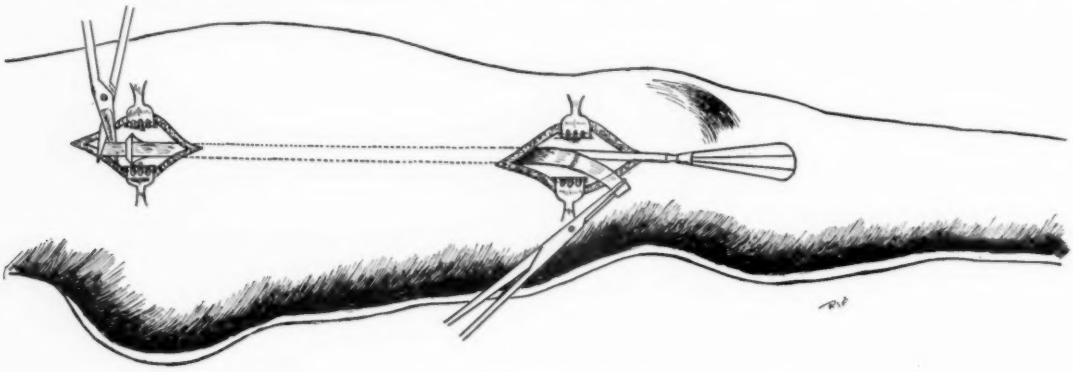


Fig. 4. Stripper method of obtaining fascia suture (final step).

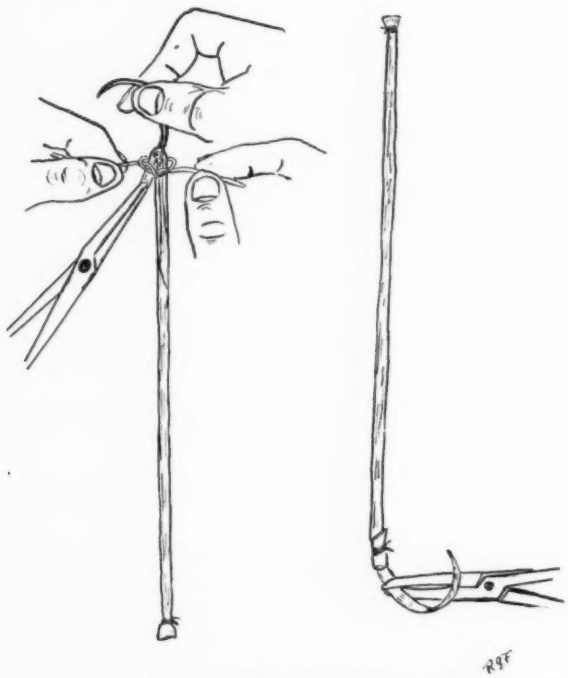


Fig. 5. A. Method of threading Gallie needle. A strip of fascia is tied securely into Gallie needle with silk, to prevent unthreading and a ligature of silk is tied around terminal end to prevent it from splitting. B. Fascial suture ready for use.

4. Now incise a strip of fascia in the line of fibers equal to the width of the stripper and cut it transversely at the lower end where the fascia is always thicker.

5. The strip of fascia is easily threaded in the stripper with the aid of my fascial threader. The threader is a thin, half-curved steel band, ½ inch wide and 4 inches long and has three small teeth ¼ inch from its end. The teeth are engaged in the substance of the cut fascia at the lower thickened end of the strip, which is now threaded into the lumen of the stripper. (Fig. 3.)

6. Remove the fascial threader and grasp the free end of the strip with a Kocher forceps. Push the stripper upward, holding the Kocher forceps taut. (Fig. 4.)

7. To cut the upper end of the fascial strip, incise the skin and subcutaneous tissue longitudinally in the upper part of the thigh where the stripper is visualized by a bulge. The stripper is then exposed and the attached end of the fascial strip is cut off. The two skin incisions are closed with interrupted silk sutures and a compression bandage applied.

8. After the fascia has been removed from the body it is cut (preferably with scissors) into strips ¼ inch wide. To save time in threading the needle it is advisable to use a Gallie needle which has a very large eye. The needle is threaded and the strip of fascia is tied securely into the needle with silk, to prevent unthreading. A ligature of silk is tied around the terminal end of the suture to prevent it from splitting when drawn through the tissues.

Gallie Operation: The general plan of the Gallie operation resembles that of the Bassini repair.

Technique of the Insertion of Living Sutures in Inguinal Hernia: The following is a brief description of the technique which

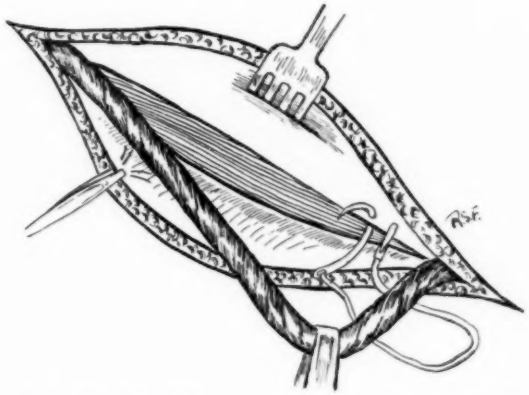


Fig. 6. Beginning of first step of basket weaving method (inguinal hernia). Needle and suture pass through Poupart's ligament from anchored end in sheath of rectus muscle and conjoined tendon.

I have adopted. It has given me excellent results.

1. The usual skin incision 4 inches long is made parallel to Poupart's ligament about ½-inch above. The spine of the pubis is exposed to the lower end of the incision.

2. The aponeurosis of the external oblique is slit up its full length in the direction of the fibres.

3. The aponeurosis is dissected well back on the inner side towards the rectus muscle, giving a full exposure of the internal oblique muscle.

On the outside the aponeurosis is dissected until Poupart's ligament is exposed to the pubic bone.

4. The sac and cremaster muscle are seized with a pair of thumb forceps and lifted up, and the muscular fibers are pushed aside by means of another pair of thumb forceps, thus exposing the sac plus the cord which are held together by the infundibuliform fascia.

5. The next step is to separate the infundibuliform fascia which surrounds the sac and cord in common, grasp the exposed sac with a clamp and separate the cord from the sac.

6. The sac is opened. The proximal end is dissected upward until it widens out in the general peritoneal cavity.

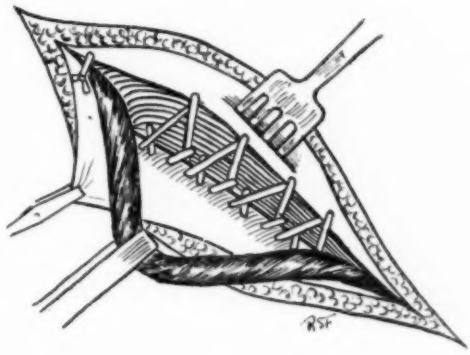


Fig. 7. Basket weave suture method (inguinal hernia). Insertion of second row of sutures. These are fixed above by a deep bite into line of junction of external oblique muscle and external oblique aponeurosis and placed close together.

7. The sac is transfixed high up with a No. 1 plane catgut ligature and tied off, so that there is no longer any funicular process of peritoneum.

8. The cord is then held up by means of a piece of tape and artery forceps.

9. The fascial sutures are then transferred to the hernia wound and the suturing commenced. (Fig. 5.)

10. The anchoring stitch is passed through the anterior layer of the rectus sheath and rectus muscle close to their attachment at the pubic bone. From here it crosses the gap in the abdominal wall to the pubic spine, where it is securely fixed into the periosteum of the termination of Poupart's ligament. In this way a strong support is provided at the place where the hernia is most apt to occur. (Fig. 6.)

The suture is then continued in an outward direction to the reflected portion of Poupart's ligament until the internal ring is reached, thus closing the edge of the internal oblique muscle. Here the suture is knotted and then passed to the outer side of the cord, so that a new ring of fascia lata is formed. This stitch was first suggested by Coley.

By this means the weak spot produced by the passage of the cord through the abdominal wall is adequately supported.

In some cases a single line of sutures might be sufficient to establish a cure, but in the majority of patients, with a direct hernia the abdominal muscles are so weak that they cannot be depended upon to resist severe intra-abdominal pressure. (Fig. 7.)

To prevent the possible stretching of the internal oblique muscle, therefore, we insert a second line of sutures, superimposed upon the first, which passes from the strong abdominal aponeurosis at the junction of the external and internal oblique muscle and from the anterior sheath of the rectus muscle to Poupart's ligament. No attempt is made to draw these aponeurotic structures tightly together as the sutures are simply drawn sufficiently taut to make them lie flat. They are placed close together and made to pass under or through the first line of sutures, as in weaving a basket. In this way the weak spot in the abdominal wall is completely and permanently covered with muscle and strong fascia, and if care is taken in securing good anchorage for the sutures, there will appear no possibility of a hernia ever pushing its way through.

11. The cord is now dropped back into its new bed and the external oblique aponeurosis closed over it with a No. 1 chromic catgut suture and the skin wound is closed with interrupted silk sutures.

FEMORAL HERNIA

Recurrence is very common after operation for large femoral hernia, due mainly to ineffectual closure of the hernial opening. The usual operation consists of high ligation and excision of the sac, after which the recurved portion of Poupart's ligament is sutured to the pectineus muscle with kangaroo tendon or chromic catgut. Recurrence is due to two factors: first the constant pull exerted on the sutures by the muscle of the thigh and abdomen, and second the unsatisfactory union that is common when muscle is sutured to fascia.

If a securely anchored, properly placed living fascial suture is used the latter will remain in situ indefinitely and a permanent cure can be expected in every case.

Technique. Make an oblique incision 3 inches long parallel to and below Poupart's ligament directly over the hernial opening. Deepen the incision to the fascia lata of the thigh and expose Poupart's ligament, the falciform process of the fascia lata, the pectineus muscle and the neck of the sac.

A small firm pad of fat is always pushed through the femoral canal by a hernia and is always identified directly over the exit of the canal. The fat is seized with a pair of thumb forceps and is separated from the femoral vein and adjacent structures by careful blunt dissection.

When the sac is identified beneath the pad of fat, it is dissected free, opened between two clamps and then ligated as high up as possible.

Beginning at the medial side, the fascial suture is anchored into Poupart's ligament, is then passed across the femoral ring to be then anchored in the pectineal fascia. This suture is passed backward and forward until the hernial opening is entirely closed.

When the sutures are drawn sufficiently taut to make them lie flat, there will be no constriction of the vessels as they pass into the thigh.

The living fascial suture method of closure is of special value in recurrent femoral hernia and in femoral hernias of large size.

VENTRAL HERNIA

This type of hernia is usually due to wound infection but may be caused by prolonged drainage or faulty closure. In these cases the usual method of closure depends on the overlapping of muscle and fascia over the defect. As a result, a suture is usually placed under considerable tension and in larger defects it may be impossible to approximate the edges of the opening.

Living fascial sutures are particularly valuable in the cure of these cases.

Technique. Make an elliptical incision, excising the old operative scar. Deepen the incision very carefully, exposing the sac. The sac is opened with the greatest care since frequently the intestines will be found densely adherent to it.

When this condition is found to exist the intestines should be freed with a knife, leaving islands of sac adherent. Free the peritoneum from the overlying structures for about an inch on either side. Excise the sac and close with a No. 2 plain catgut suture.

The closure of the defect is effected with fascial sutures entirely. When the fascial edges of the abdominal wound can be approximated without tension this is done with two layers of continuous living fascial sutures.

In cases with larger defects no attempt is made to approximate the edges of the fascial wound, the defect being closed by weaving living fascial sutures across it, as one would darn a hole in a sock.

The author has personally performed thirty-five fascial repairs up to July, 1932.

Recurrent inguinal hernia	11
Direct inguinal hernia	15
Indirect inguinal hernia	4
Large ventral hernia	3
Femoral hernia	2
Total	35

CLOSING VERY LARGE VENTRAL HERNIAS

The repair of large ventral hernias with autogenous fascial sutures made from fascia lata has been quite satisfactory and there is no question that it has greatly reduced the incidence of recurrence and widened the field in which operation is indicated. There are some cases, however, in which the hernial ring is so large that no method of suture can adequately close the opening. There are others in which, while it is possible to draw the edges of the opening together by tight lacing of the suture, this can be done only with such an increase of the intra-abdominal pressure as to seriously endanger the life of the patient. In most cases the use of fascial sutures has proved successful but unfortunately, in a certain number, recurrences have developed which subsequent operation has shown to be due to protrusion through chinks between the sutures.

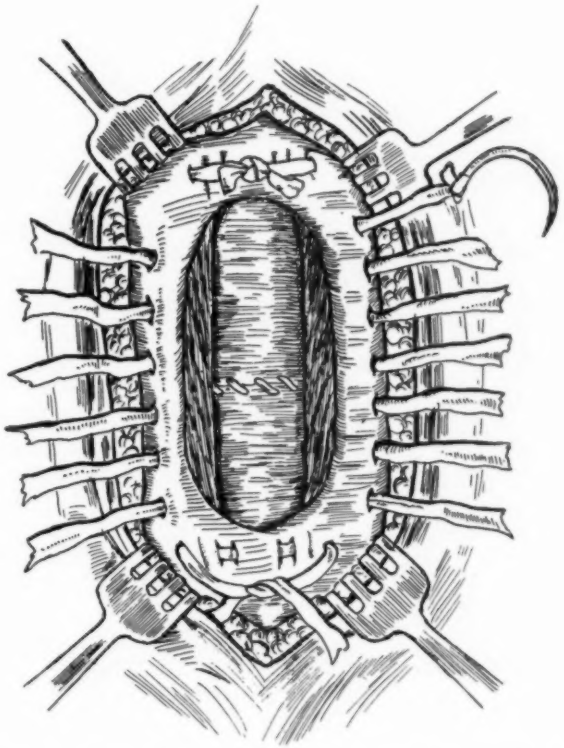


Fig. 8. Very large ventral hernia, opening closed by Gallie method. Two sheets of fascia lata are placed edge to edge and sutured; tails pass through edge of hernia ring and strips of one side of opening are tied to those of the other, bringing edges as closely together as seems desirable.

This has been found in a combination of the patch transplant with the living suture. It will be remembered that the defect in the patch transplant was that it could not be depended upon to heal strongly into the opening. There was no doubt that it could be expected to live but there was great doubt in regard to the strength of the scar and areolar tissue that joined its edges into the hernial ring. (Fig. 8.)

Technique. This uncertainty can be overcome by using as a patch transplant

a sheet of fascia lata whose ends have been split into quarter-inch strips so that it resembles the old-fashioned many-tailed abdominal bandage. When the strips have been threaded on needles they are passed through the thick margins of the ring and those of one side of the opening are tied to those of the other, bringing the edges as closely together as seems desirable. In this way a strong aponeurotic structure, free from chinks and other weak spots, is securely fastened into the defect and may be depended upon to close the opening permanently.

The method is particularly applicable to large ventral hernias and most frequently to hernias resulting from suppuration following operations on the gall bladder and stomach. It is useful also in cases of large direct inguinal hernias, particularly those in which the abdominal wall is feeble and in which several unsuccessful operations had previously been performed.

In the case of the ventral hernias a few special points in technique should be observed. In preparing the hernial opening for the closure no attempt is made to separate the various layers from one another as this definitely weakens the wall. The peritoneum is pushed back from the edge of the opening for half an inch or more so that the needle may be passed from within outward through the edge of the ring without entering the abdominal cavity. If the hernial opening is longer than 3½ inches it will be necessary to cut two patches from the fascia lata which will be laid side by side across the opening. As a rule, two patches of fascia, 5 inches by 3½ inches, can be obtained from the lateral aspect of a single thigh. The ends of the patches are then split into strips about ¼ inch wide and by means of a fascia needle passed through the edges of the ring as shown in Figure 8. If a second patch is needed it is laid edge to edge with the first and the two are sewn together with a fine strip of fascia lata threaded on a needle. At the ends of the opening, special precaution is taken to weave the tails into the edge of the ring so as to prevent a protrusion over the end of the fascial sheet. When all the tails have been drawn through the abdominal wall they are tied together, each to its fellow of the opposite side, and the edges of the opening drawn together as closely as seems safe. If they can be brought into contact without too much tension, so much the better, but, if they cannot, the surgeon may rest assured that the deep side of the defect in the abdominal wall has been permanently closed off. Often it is possible, where the deep portion of the opening cannot be drawn together, to close the anterior rectus sheath with catgut or a suture of fascia and this shuts off the sheets of fascia from view and seems to be an advantage. Care should be taken to oversew the knots in the tails of fascia with chromic catgut as these have a strong tendency to slip and untie when strain is put upon them.

CONCLUSIONS

1. Attention is called to the great value of fascial sutures in the cure of direct inguinal hernia, large oblique inguinal hernia in patients past middle age, ventral hernia and large femoral hernia.

2. Living fascial sutures remain in situ indefinitely and if securely anchored and properly placed will close any hernial defect permanently.

3. Large ventral hernia can be cured only by use of fascial sutures.

4. The disfiguring scar, postoperative disability and operative infection has been largely eliminated by use of a fascial stripper.

5. The fascial separator and threader devised by the author greatly facilitate the fascial stripping operation.

Note: The instruments referred to are made by George Tiemann and Company.

SPIVACK'S METHOD OF GASTROSTOMY

WITH A BRIEF CRITICAL REVIEW OF SOME OF THE PREVIOUS METHODS AND A REPORT OF 3 CASES

NELSON H. LOWRY, M.D., F.C.S., AND S. SORENSON, M.D.

CHICAGO, ILL.

GASTROSTOMY is one of the oldest operations in the history of gastric surgery. There are reasons to believe that it was already known in the earlier part of the seventeenth century.

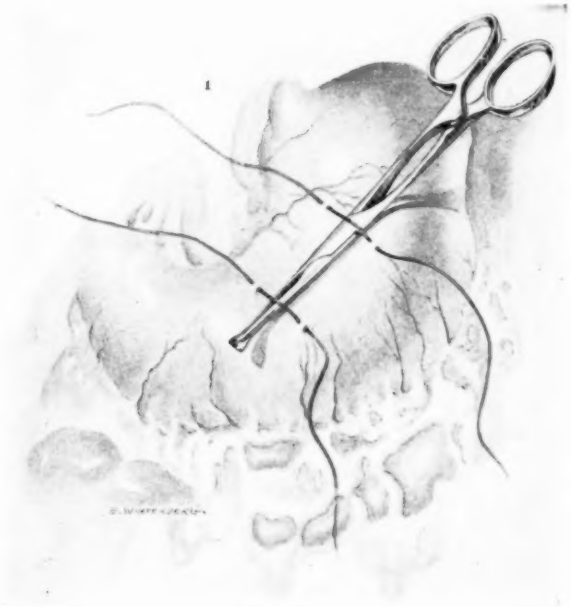


FIG. 1.

To our knowledge there are between thirty and forty methods of gastrostomy recorded in medical literature. The reason for this high number lies in the fact that all these methods proved to be more or less unsatisfactory and in many instances cause of untold misery and suffering for the patient.

Ever since Egelberg, a Norwegian military surgeon, advised gastrostomy in cases of stricture of the esophagus, surgeons have been confronted with two main obstacles which have continued to be serious drawbacks to all the different methods of gastrostomy. Of primary importance is leakage of the gastric contents which occasionally, particularly in the pre-antiseptic days, results in fatal peritonitis but more often causes eczema of the skin around the gastrostomy opening which greatly interferes with the comfort and well-being of the patient.

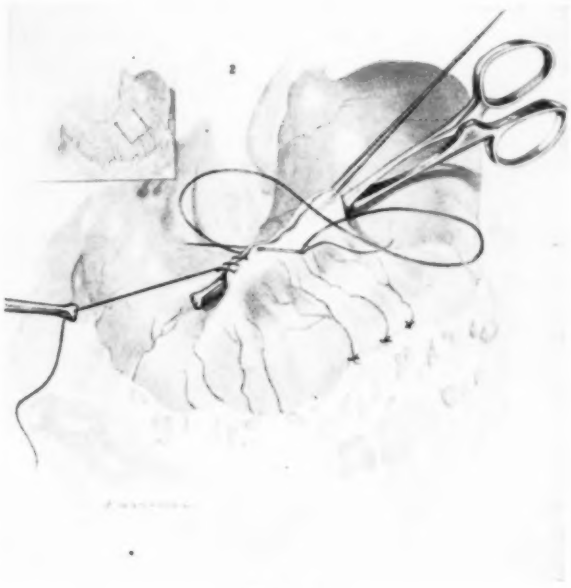


FIG. 2

Of secondary importance is spontaneous obliteration of the fistula which also occasionally happens, especially in cases where the fistula is lined with serosa. Quite frequently the obliteration can be so complete as to render feeding of the patient impossible.

It is not without some interest in this connection to observe the requirements for an ideal method of gastrostomy which would, of course, be an operation of choice and to see to what extent some of the older surgeons succeeded in obviating these two obstacles just mentioned.

An ideal method of gastrostomy should be:

(a) Absolutely "watertight," i.e. not permit leakage of the gastric contents which always is irritating and painful to the patient. This factor is of paramount importance and as is evident from the descriptions of all the previous methods, this leakage was the factor that surgeons attempted to overcome in different ways, sometimes paying meager attention to other factors.

(b) The canal should be lined with mucosa as the serosa has a tendency to obliterate when irritated by a foreign body.

(c) It should not require a large piece of the stomach as in most cases requiring gastrostomy the stomach is small and contracted.

(d) It should be simple in technique so as not to consume much time. With the introduction of blood transfusion and glucose solution intravenously or by proctoclysis and improved methods of anesthesia this factor is not as important today as it was fifteen or twenty years ago.

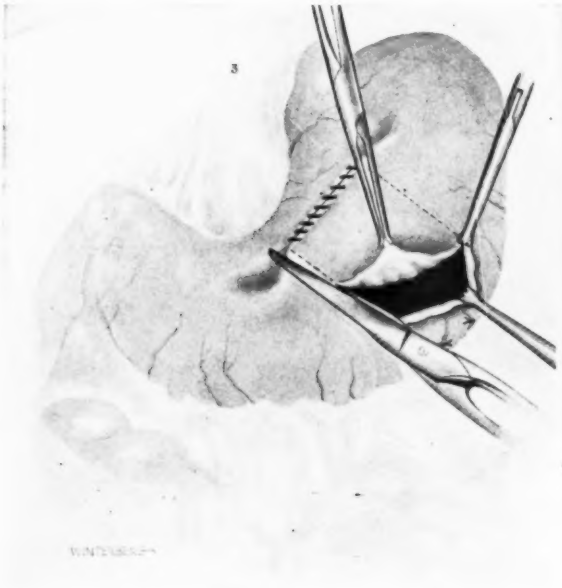


Fig. 3.

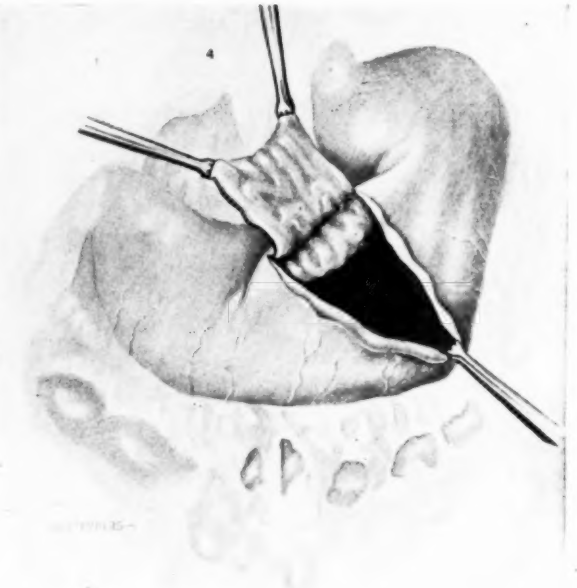


Fig. 4.

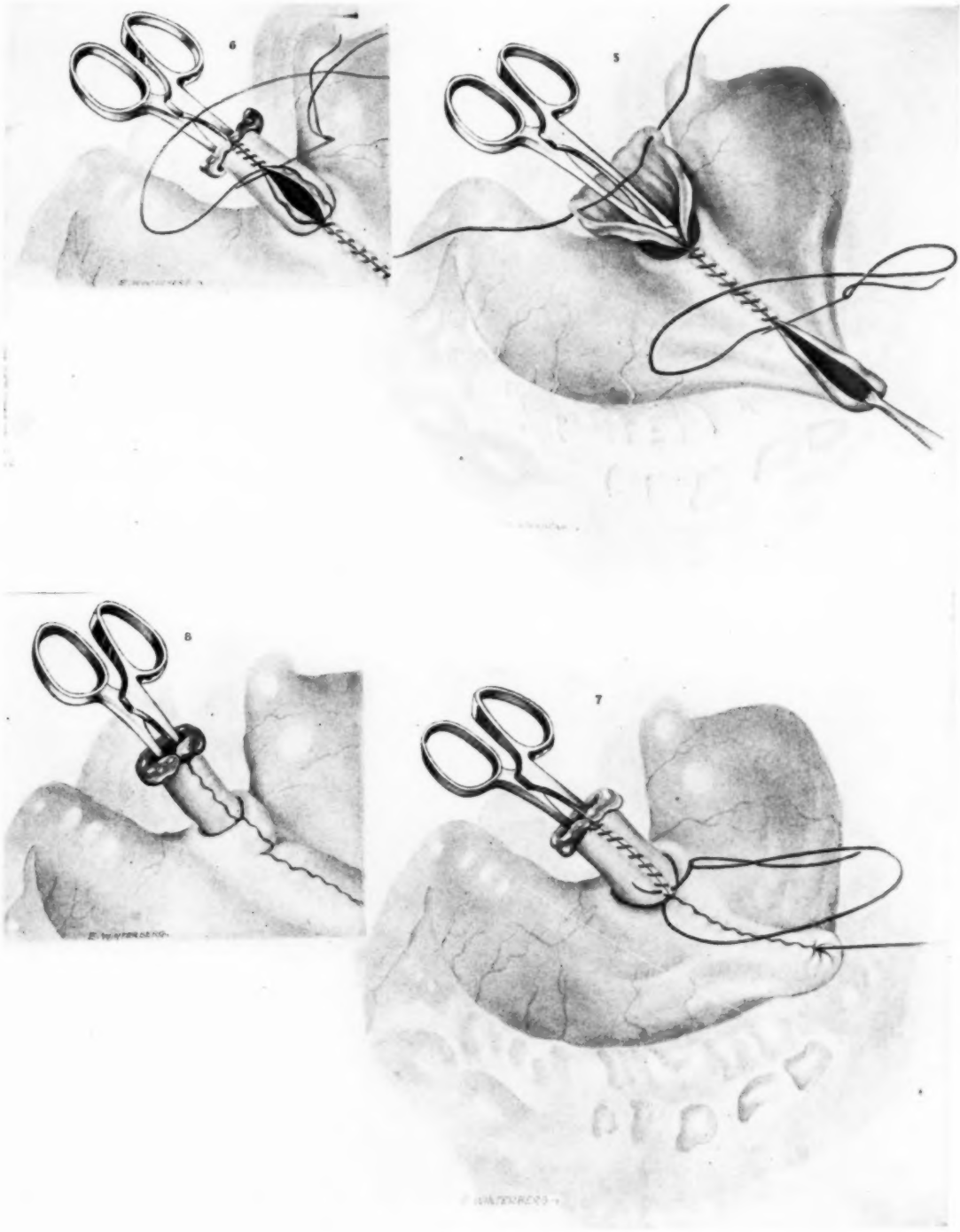
All these attempts to prevent obliteration of the canal and to make the fistula watertight may be classified and presented in several groups as follows:

1. A cone is formed from the anterior wall of the stomach so that the mouth of the cone is compressed by the surrounding structures. An example of this group is the method of *Hahn*. Hahn stitched the stomach in the eighth intercostal space in order to use the elastic costal cartilages as a compression stopcock which would prevent enlargement of the fistula and leakage of the gastric contents. Experience, however, has shown that the costal cartilages soon lose their elasticity and that this procedure is not proof against leakage.

2. Formation of a subcutaneous canal through which the stomach is pulled. Prevention of leakage is secured by applying bandages over the entire length of the canal. The methods of *Sabanejew-Frank*, *Jaboulay* and *Lucy* are examples of this group. Jaboulay and Lucy modified Sabanejew-Frank method and these modifications are said to have some advantages over the original method. However, this

method requires a large stomach and in cases where it is small and contracted this method would prove disadvantageous.

watertight results. An example is the method of *Ullmann* which does not need further description.

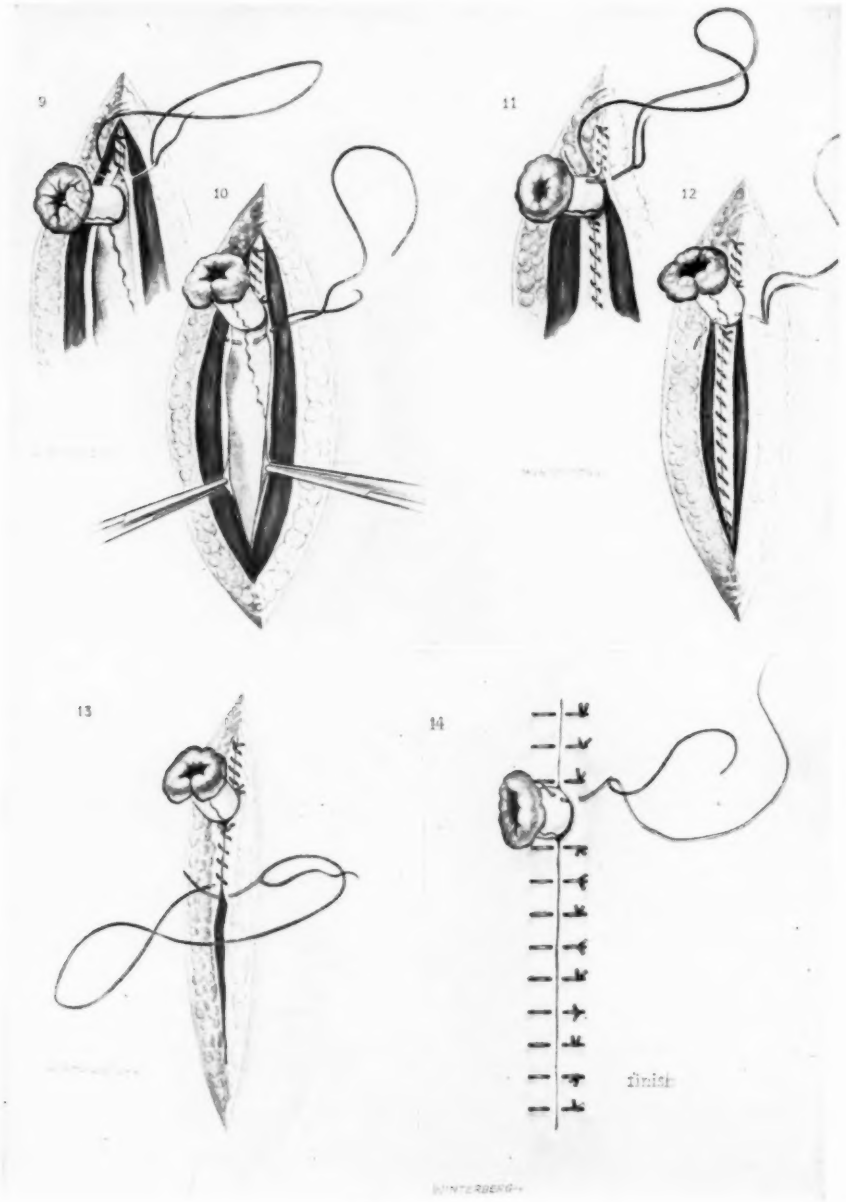


Figs. 5–8.

3. A cone is formed from the anterior stomach wall which is rotated 180 degrees at the external opening so as to secure

4. Formation of a sphincter from M. rectus abdominis. Examples are the methods of *Von Hacker* and *Girard*. Both

these methods are based on the idea that this artificial sphincter would be under the control of the will and that the patient would, therefore, have voluntary control of the gastrostomy opening. These methods never became practical on account of repeated failure to produce an artificial sphincter from a group of voluntary muscles.



Figs. 9–14.

5. Formation of an oblique canal in the anterior wall of the stomach. Example: method of *Witzel* and its modifications (Marwedel, Schnitzler). In this group can also be included *Stamm's, Kader's* and *Fontana's* methods. The difference between these methods and those of Witzel's type is that the canal runs perpendicular to the anterior wall of the stomach, whereas in Witzel's method it runs parallel. The disadvantage common to all the methods in this group is that the fistula is lined with serosa and tends to obliterate.

6. Formation of a valve in a contracted cone from the stomach wall. Example: method of *Senn*. In fact there is actually no valve which would prevent leakage from the stomach.

7. Implantation of a loop of jejunum into the anterior wall of the stomach. An example is the method of *Tavel*. This is a very complicated procedure and the fistula formed is by no means watertight.

8. A small tube lined with mucosa is formed from the anterior stomach wall. Example: methods of *DePage* and *Janeway*. As the tube is lined with mucosa it does not obliterate but there is nothing to prevent escape of gastric contents.

In this classification we have included some of the best known methods of gastrostomy and examples of each group.

Spivack's method consists in making a tube from the anterior stomach wall *with a valve at the base*. The tube is lined with mucosa and does not tend to obliterate. Slightest intragastric pressure flips the valve into the internal opening of the tube and closes it so completely that not a single drop of gastric contents can escape.

As may be seen by comparing these groups, Spivack's method stands in a class by itself and is not a modification of any other method. It was first described by its originator in 1929.[1]

TECHNIQUE

The technique of this operation as described in the original article but somewhat modified by the originator is as follows:

Step 1. The stomach is brought out of the abdomen through a median or left paramedian incision. A quadrangular-shaped area 2 by 4 inches, depending, of course, on the size of the stomach, is mapped out on the anterior stomach wall. The upper half of this area is doubled according to the technique shown in Figure 1.

Step 2. A forceps is placed inside of the fold and the two ridges formed are united by a continuous suture (Fig. 2).

Step 3. The vessels at the greater curvature that are bound to be cut are carefully ligated. Two Allis forceps are then placed about 1½ to 2 inches below the ends of the fold previously made and at a right angle to each other. The stomach is cut open with sharp scissors along the greater curvature. The cut edge of the stomach is grasped with an Allis forceps right in the middle of the incision so as to prevent the stomach from slipping away and contaminating the field (Fig. 3). The opening is now extended toward the lesser curvature (Fig. 3) and a U-shaped flap made from the anterior stomach wall at the base of which is the fold previously made (Fig. 4). It should be borne in mind that the vertical incisions should *not* extend beyond the fold in order to secure watertight results.

Step 4. The opening in the stomach is sewed up with silk or tanned catgut sutures, starting at the base of the flap and extending toward the greater curvature (Fig. 5). In order to avoid catching the valve in the stitch, a forceps is placed inside of the stomach and the fold pushed away from the field (Fig. 5).

Step 5. The flap made from the anterior stomach wall is sewed up in a similar manner, starting at the upper angles, and a tube is made with a valve at the base (Figs. 5 and 6).

Step 6. The tip at the greater curvature is inverted by a purse-string suture and the whole suture-line is reinforced by a right-angle Cushing stitch. At the point of junction between the tube and the stomach wall, some kind of a cuff is made by taking a stitch in the tube just above the weak angle; thereby the tube is pushed a little downward so that the base of it is surrounded by the wall of the stomach (Figs. 7 and 8). This procedure prevents any possible leakage to take place from the angle and reinforces it considerably.

[1] *Bruns Beitr. z. klin. Chir.*, 147: May 10, 1929.

Step 7. The tube formed from the anterior stomach wall is now brought into the wound and the edges of the peritoneum are sewed to the stomach around the tube by two seromuscular stitches which are placed *at the base of the tube* but not in the tube itself (Figs. 9 and 10). This is an important step and should never be overlooked. The stomach, whether full or empty, has a tendency to pull the tube into the abdomen and any stretching or pulling of the tube during the first few days after the operation may result in necrosis of the tube or breaking of the cuff previously described and produce leakage from the angle with ensuing peritonitis.

Step 8. The fascia is sewed around the tube in a similar manner, two stitches being taken in the tube penetrating the seromuscular coats only (Figs. 11 and 12). After the wound has been closed up the skin edges are stitched to the top of the tube. The final results are shown in Fig ure 14. When doing these final steps, care should be taken not to constrict the tube.

According to the originator the principle involved in this method is based on the well-known fact that the surface of the mucosa of the stomach is much larger than that of the serosa and muscularis and as soon as the seromuscular coats are incised the mucosa tends to protrude through the incision. This fact is taken into consideration when making the valve previously described which closes the base of the tube hermetically and prevents leakage.

This operation is not technically complicated. In the hands of an experienced surgeon it should not take more than twenty minutes and it has been repeatedly shown that this method can be performed on a very small and contracted stomach. There is a case on record where it was performed on an infant two days old.

There are, to our knowledge, about 15 cases on record on which Spivack's method of gastrostomy has been successfully performed by different surgeons.

We take the opportunity of reporting here, briefly, the first 3 cases on which this method was performed, in order to show the advantages of this method and point out a few pitfalls in the technique.

Case 1. M. Z., white, male, seventy-eight years of age. Admitted to the Edgewater Hospital, Chicago, August 6, 1929. When admitted the patient stated that he had been well until about nine years ago. At that time he had swallowed a solution of some corrosive material which resulted in stricture of the esophagus and its characteristic symptoms. The patient was cured of this condition after six weeks of treatment and remained well until just recently. At the time of admission he was unable to swallow even liquids. *X*-ray examination revealed a large sacculated aneurysm of the arch of the aorta and a diagnosis of aneurysm of the aorta compressing the esophagus was made. Spivack's method of gastrostomy was performed by Dr. Julius L. Spivack and one of us (N.H.L.) under splanchnic and regional anesthesia as the patient was extremely dehydrated and a bad surgical risk. He survived the operation, however, but succumbed sixteen days later from lobar pneumonia.

No difficulty was ever experienced in inserting a rubber tube into the stomach for feeding purposes and no leakage was ever noticed. It is worth mentioning that at the time of operation the patient vomited when the gastric part of the operation was just completed. While straining the stomach became very much distended and the gastric contents were ejected through the constricted esophagus but not a single drop came out of the tube.

This incident demonstrated conclusively that the gastrostomy was absolutely watertight.

Case 11. G. M., white, male, forty-eight years of age. Admitted to the Edgewater Hospital, Chicago, August 16, 1929. Gradually over a period of one year the patient has noticed increasing dysphagia and lost about 20 lb. of weight. Difficulty was at first experienced in swallowing solid food but within the past few months the dysphagia has become so complete that at the time of admission the patient was unable to take food in any form. Consequently, the patient was very emaciated and dehydrated. The diagnosis was malignant stricture of the esophagus. Spivack's method

of gastrostomy was performed by Dr. J. L. Spivack and Dr. Loren Wilder, on August 17, 1929. The stomach was freely moveable but quite small and contracted.

The patient made uneventful recovery and was discharged from the hospital September 10 in an excellent condition. When last heard of, eighteen months after leaving the hospital, the patient was still alive and feeling quite comfortable. An interesting feature about this case was the fact that six months after the operation the patient came back to Dr. Wilder stating that some time after he went home he had discovered that he could swallow almost any kind of food without difficulty and that he had not been using the fistula for a few months. As he was again experiencing increasing difficulty in swallowing he came back to the doctor because he was afraid that the fistula might have closed up since he ceased using it. Even then Dr. Wilder found no difficulty whatsoever to introduce a rubber tube and feed the patient. It is worth notice that the patient never experienced any inconvenience or annoyance due to the operation. The skin around the opening was perfectly normal and showed no signs of irritation.

This case illustrates that the fistula is not only watertight but, also, that it has no tendency of obliteration even when left alone for several months.

Case III. M. A., white, female, aged fifty-two. Admitted to the Ravenswood Hospital, Chicago, October 2, 1929. The patient complained of pain at the lower end of the sternum of three weeks' duration which appears immediately after eating and is followed by nausea and vomiting. Lately she has been able to swallow liquids only. Has lost 30 lb. of weight in the last three months. *X*-ray examination of the esophagus showed barium remaining in the distal portion of the esophagus just proximal to the diaphragm. Diagnosis: Carcinoma of the distal end of the esophagus. Spivack's method of gastrostomy was performed by Dr. Loren Wilder. The stomach was free and moveable so that it could be brought forward. At the cardiac end was felt a mass about as large as normal kidney, hard and nodular and fixed under the diaphragm.

The patient made uneventful recovery and was discharged October 20 in an improved condition. She died fourteen months later from general carcinomatosis. Autopsy revealed that the whole stomach including the tube was involved but *the valve at the base of the tube was still intact and watertight.*

Another case of similar interest, operated upon by Dr. Spivack and Dr. Nelson M. Percy, is on record at the Augustana Hospital, Chicago. The tube sloughed away but even so there was no leakage from the fistula which showed that the valve was still intact. The patient died from bronchopneumonia on the seventh postoperative day. The stomach was found involved in a carcinomatous growth but was watertight.

The cases here reported and several other cases prove beyond all doubt that Spivack's method is superior to any other method of gastrostomy so far devised. The two major disadvantages common to most methods of gastrostomy, leakage and obliteration of the canal, have been completely obviated and as it fulfils all the other requirements of an ideal method of gastrostomy, it is, to our judgment, an operation of choice.

Provided the surgeon who attempts to perform this operation follows the technique here described, he can be assured of uniformly good results.

There is one point in technique we want to emphasize. *Never leave a rubber tube inside of the canal after completion of the operation.* This mistake may result in pressure necrosis of the tube made from the stomach wall and render feeding of the patient quite difficult. There are, namely, two cases on record where this occurred due to misunderstanding on the part of the interns. Fortunately the necrosis did not reach the valve so no leakage took place.

We wish to state, also, that Spivack's method is not only indicated in cases of permanent gastrostomy. One of us (N. H. L.) had some time ago occasion to perform this operation on a patient with a benign stricture of the esophagus so as to make it possible to dilate the esophagus from below. That was successfully done through

the gastrostomy opening. Few months after the patient was relieved and well the gastrostomy tube was removed and the stomach sewed up. The patient made rapid recovery. The feasibility of inserting radium seeds into the stomach in cases of carcinoma of the cardia may also be suggested.

SUMMARY

1. The disadvantages common to the previous methods of gastrostomy are: (1) leakage of the gastric contents, causing painful eczemas and (2) spontaneous obliteration of the fistula, rendering feeding impossible.

2. In order to overcome these difficulties a tube is made from the anterior wall of the stomach, lined with mucosa and does not, therefore, have a tendency to obliterate. At the base of the tube is formed a valve which prevents leakage.

3. This operation can be performed on a stomach of small size. It has been performed on an infant two days old (for tracheoesophageal fistula).

4. The technique is not complicated; however, the details should be meticulously followed in order to secure good results.

5. As this method fulfils all the requirements of an ideal method of gastrostomy it should be an operation of choice.

VAGINAL STERILIZATION

INDICATIONS AND OPERATIVE TECHNIQUE*

A. E. KANTER, M.D., F.A.C.S., AND A. H. KLAWANS, M.D.

CHICAGO, ILL.

STERILIZATION of the female is a recognized procedure and is performed as a prophylactic measure in order to save, or at least prolong, the life of the individual. The operation is done at the insistence of a specialist in one of the diagnostic fields of medicine because that physician feels if the patient were to become pregnant at a subsequent time her life might be endangered. The rationale of sterilization is to increase the span of life in those women who are afflicted with chronic disease which may become aggravated during the course of a pregnancy. This is true of all chronic diseases to which the human race falls prey with the exception of syphilis which is more amenable to treatment during pregnancy than it is at other times. If we continue to allow these women to conceive and carry on with their pregnancies we are taking unnecessary chances with the lives of our patients, we are adding unnecessary hours of worry and anxiety to our lives, and we are defeating all the other work we are doing in an effort to show a decrease in our maternal mortality.

The responsibilities of the medical profession lie in the direction of timely and adequate diagnosis of an existing medical, neurological, or mental condition. The surgeon should not take it upon himself to pass the severity of the existing condition or the amount of extra strain that that particular individual can stand in the form of pregnancy and labor. All patients in whom there is any small bit of doubt should have the advantage of a thorough examination by a competent specialist. It is only by such unselfish cooperation that the medical profession can honestly have all physically deserving patients sterilized, and by this means show much needed progress toward a substantial reduction in the maternal mortality statistics.

The commonly practiced contraceptive measures are, in a way, methods for temporary sterilization, but the uncertainty of their ultimate efficiency adds worry to the already troubled mind of the chronically ill patient. Our contention is that any contraceptive used over long periods of time is futile because it is either unsafe or adds further disease to that already present. Stem pessaries that are inserted into the cervical canal are actually harmful. Every patient who wears one of these devices develops an endocervicitis and cervicitis from the constant contact between the foreign body and the highly specialized cells of the endocervical canal. Leucorrhea always develops, and many women have a residual discharge that is so intractable as to necessitate amputation of the cervix or even total hysterectomy. In several cases which we have seen, the patients had presented themselves to their physicians for periodic removal and cleansing of the stem pessary. When the device was removed from the cervical canal virulent organisms were liberated, traveled through the pelvic lymphatics into the general circulation and fatal generalized sepsis resulted.

The cup pessary is undesirable for several reasons. It is necessary to remove the pessary before the onset of each menstrual period and to re-insert it after the period is ended. Thus it is necessary for the patient to visit her physician twice each month for removal and re-insertion of the cup. Many women do not have

* From the Department of Obstetrics and Gynecology, Rush Medical College.

rigidly regular periods, and if a patient begins to menstruate at an unexpected time the cup blocks the cervical exit for the

Finally, we have the commonly practiced coitus interruptus. If followed out properly this method is safe for the prevention of

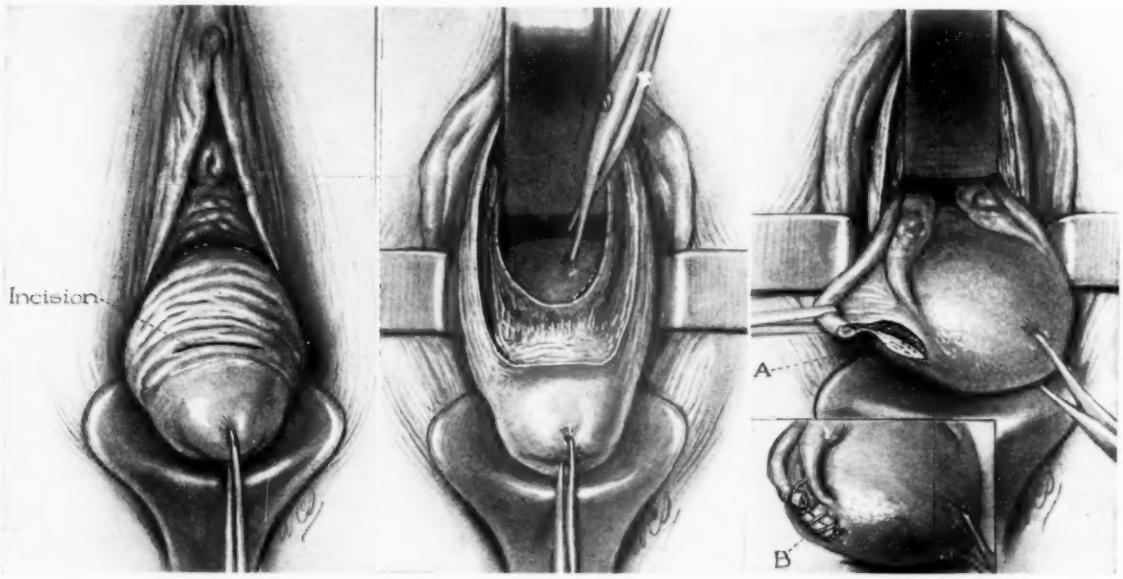


Fig. 1. Fig. 2. Fig. 3.

Fig. 1. Incision in cervical mucosa.
Fig. 2. Vaginal mucosa and bladder reflected. Peritoneum opened, uterine body visualized.
Fig. 3. A. Resection of tube and uterine cornu. B. Closure of uterine cornu.

menstrual blood and there is a damming back of this blood. If the reflux is sufficient in amount it may spill through the fimbriated end of the tube and result in the very annoying and hard to treat endometriosis.

The use of medicated jellies or medicated douches is bound to fail in about 5 per cent of cases, and if we depend on them in our patients who must not become pregnant there is always the fear that the contraceptive will not prove successful. The semen is deposited in the posterior vault of the vagina, and quite frequently the patient fails to reach this place with the douche or the jelly and pregnancy may result.

The use of the condom is a comparatively safe measure. But even here unforeseen accidents occur and the purpose of the contraceptive is defeated. Not infrequently during the course of coitus the condom breaks and the parties concerned are unaware of this accident. Thus the relative safety of the condom is not absolute.

pregnancy, but the effects of this practice on the individuals using it may prove disastrous. Primarily there is the fear that premature ejaculation may take place and semen be deposited in the vagina. The nervous strain attached to this constant worry will eventually tell on the individual who has some illness which absolutely contraindicates pregnancy. Secondly, the persons who practice coitus interruptus withdraw before the orgasm is reached, and in this manner they are constantly being fomented to the point where pelvic congestion reaches a maximum without culmination of the act. This is an underlying factor in the production of so-called nervous individuals and is prone to produce irritable, dissatisfied, and nervously unstable patients. Thus we see that the practice of coitus interruptus adds nervous strain to an already damaged body and our medical task is made a more difficult one.

After an analysis of the most common contraceptive practices we are forced to the conclusion that the patient who, for some medical reason, is in need of sterilization is not adequately protected by the use of contraceptives. We cannot rely upon any of the foregoing measures to keep our patients from becoming pregnant indefinitely. The obvious conclusion, then, is that actual sterilization by operation is the only procedure that will insure both sterility and the maintenance of the mental balance of the sensitive patient.

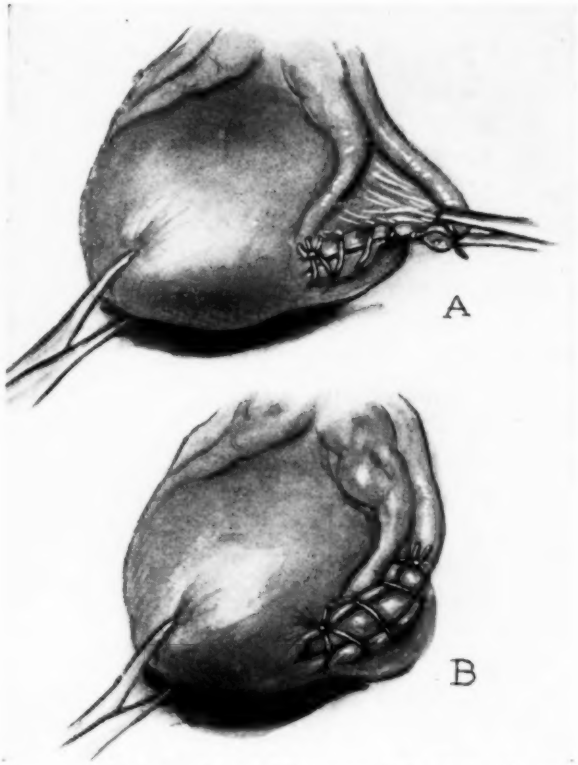


Fig. 4. A. Tube and broad ligament being brought over uterine horn. B. Peritonealization of uterine horn by tube and broad ligament. Note tube ligated by each stitch.

In performing the operation for sterilization we prefer to use the vaginal route and we advocate that route of attack to all surgeons who are called upon to do the operation because of its technical simplicity and because it is much easier on the patient. Gas anesthesia can be successfully employed for the vaginal operation, while the abdominal approach is difficult and at times even impossible if some ether is not used in order to get the proper amount of relaxation. If necessary local infiltration anesthesia may be used with little discomfort to the patient, but in doing laparotomy local anesthesia fails as often as it proves successful. So we see that from the point of view of anesthesia alone the ill patient is better off with the vaginal operation than when the abdominal route has been employed.

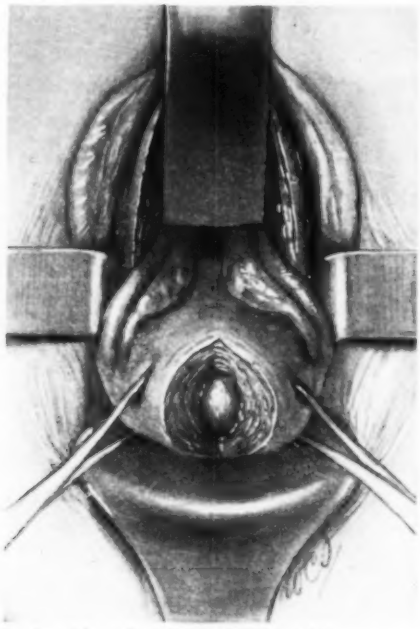


Fig. 5. Incision for fundal vaginal hysterotomy.

Any patient who has borne children has a sufficiently dilated vaginal tube to enable one to enter the abdomen from the vagina without difficulty. Most patients of this type require some vaginal plastic work which can be done in conjunction with the sterilization and thus save the necessity for a combined operation or for two separate operations. Even though the patient has not had children the procedure can be successfully carried out without a great amount of difficulty. If the vagina is not sufficiently relaxed a Schuchardt incision can be made and the vagina enlarged to enable of facile completion of the operation.

The vaginal route is also advantageous because it saves opening the abdominal wall and handling the intestines. This cuts down on the amount of postoperative discomfort, reduces to a minimum the amount of gas pains and intestinal distention, reduces the chances of a generalized peritonitis and ileus, and removes the possibility of mid-line abdominal hernia. Of secondary consideration are the time factors involved. The vaginal operation can be done in shorter time than an abdominal operation and thus the length of time of anesthesia is reduced. This may, in some conditions, be of distinct advantage to the patient. The vaginal route also proves to be an economic time saver because the patient is allowed out of bed and out of the hospital more quickly than she would be if laparotomy had been performed.

Finally, if therapeutic abortion is to be done at the time the patient is sterilized, both operations can be carried out at one time without any considerable increase in the operative difficulty, in the time necessary to complete the operation, or in the postoperative morbidity.

INDICATIONS FOR VAGINAL STERILIZATION

Cardiac Indications: Mitral lesions with myocardial changes are notably dangerous during pregnancy or labor. Any woman who has a cardiac lesion and in whom there has been at some previous time a cardiac decompensation should be sterilized. Such a patient runs a very great risk of developing another, and more severe, decompensation if she should become pregnant. Pregnancy is likely to terminate disastrously because of the extra load added to an already injured heart muscle. This applies to all previous cardiac decompensation whether occurring during the course of a pregnancy or not.

Mitral stenosis by itself does not constitute a hard and fast indication for sterilization, but any patient with a high grade mitral stenosis, with or without regurgitation, should be watched very carefully during the course of a pregnancy. If at any time in the first trimester she shows signs of cardiac embarrassment or beginning decompensation abortion should immediately be performed and she should be sterilized. Decompensations beginning in the second or third trimesters are best treated medically until viability of the child occurs, and then labor induced or cesarian section performed. This is advocated because labor or termination of pregnancy after the third or fourth month are as hard on the patient as full term delivery. Any woman who, after one or several pregnancies, develops a mitral valve lesion should be sterilized as soon as her medical condition permits. She already has her family and the danger of further pregnancies need not be hazarded.

Renal Indications: Every patient with a definite deficiency in kidney function should be sterilized because if a pregnancy ensues and the added work of elimination for both the mother and fetus is put on already damaged kidneys the result may prove dire. This is particularly true for patients who have had a true nephritis of pregnancy with marked edema, albuminuria, hyperpyrexia, and a retention of nitrogenous products as evidenced by the blood chemical findings. Unlike the acute toxemias of pregnancy, true nephritis does not entirely disappear after the termination of the pregnancy and the patients never return to their normal states. Therefore subsequent pregnancy is likely to prove of serious consequence.

Patients with tuberculosis of the urinary tract should also be sterilized because we know that pregnancy has an activating effect on tuberculosis and may stir up a quiescent affair. If the patient has had one kidney removed because of a tuberculous process she should be sterilized in view of the fact that most often renal tuberculosis is bilateral even though it may not show up in the opposite kidney for several years after the primary focus had been removed. If such a woman should

become pregnant a fatal outcome can be anticipated.

We do not want to convey the impression that every woman who has had a nephrectomy should be sterilized. We have delivered several patients who had had previous nephrectomy for calculi, and their pregnancies, labors, and postnatal courses did not deviate from the normal. Therefore we say that previous nephrectomy is not an indication for sterilization except in cases where the kidney had been removed because of tuberculosis or where the function of the remaining kidney is found, by laboratory procedures, to be below normal.

Pulmonary Indications: We all know that patients with active pulmonary tuberculosis should not become pregnant because of the activating effect of the pregnancy on the tuberculosis. The course of the tuberculosis becomes more rapid during the pregnancy. This does not mean that every woman who has had an active pulmonary tuberculosis should be sterilized. If a woman has had an arrested tuberculosis for five years with no evidence of activation during that time she may safely become pregnant and, under very careful supervision, carry to term with no ill effects. But if a woman with active tuberculosis periodically becomes pregnant and undergoes frequent therapeutic abortion, that woman should be sterilized. Or should a multi-gravida develop a pulmonary tuberculosis and progress is noted in the course of treatment of that disease she should be sterilized in order that a pregnancy should not interfere with the ultimate cure.

Otolaryngological Indications: One ear condition is known to be aggravated by pregnancy, many patients having no signs of this disease until they become pregnant. That condition is otosclerosis. If a patient suffering from otosclerosis becomes pregnant and the effect of the pregnancy on the ear condition is noticeably bad, that patient should have a therapeutic abortion and sterilization. If a patient with this disease presents herself with a history of previous gestation having caused a marked increase in the symptomatology, that patient should be sterilized because subsequent pregnancy will undoubtedly cause an increase in her difficulty especially since otosclerosis is a progressive disease. A nulligravida with otosclerosis and a great desire for a child may be allowed to become pregnant, but she should be warned that her ear condition will probably become worse. If the symptoms become so marked as to force the patient to seek relief she should be aborted and sterilized.

Tuberculosis of the larynx usually accompanies an active pulmonary tuberculosis, but rarely it may occur independently. If a patient has a laryngeal tuberculosis that patient should be sterilized under the same conditions and for the same reasons that a patient with active pulmonary lesions should have the operation performed.

Local Anatomical Indications: Local anatomical conditions, usually the result of pregnancy, frequently demand plastic repair, but these repairs are of no avail if the patient subsequently becomes pregnant and during the labor and parturition the operative repair is torn down. Large cystoceles and rectoceles, third degree lacerations of the perineum, vesicovaginal fistulae, rectovaginal fistulae, cervical lacerations extending beyond the internal os, and prolapse of the uterus fall in this group. All women presenting themselves for repair of the afore-mentioned conditions should be sterilized as a part of the operation in order to preserve the work done at the time of the operation. In doing the interposition operation the sterilization is an important part of the procedure, inasmuch as should pregnancy follow great difficulty will befall the patient and therapeutic abortion is frequently necessary to relieve a uterine or bladder incarceration. The only exception of this rule is the nulligravida with a uterine prolapse. This may be repaired without

sterilization in order to give the patient a chance to bear children.

Social Indications: Frequently we are approached by the social service departments of our hospitals and requested to sterilize certain patients for social reasons. Some of these requests we are forced to deny, but we feel that there are certain definite social indications for this operation.

There are apparently normal parents who have had several mentally deficient children. If this condition recurs in several children of the same parents there is a definite reason for sterilization in order to save these parents from bringing into being any more of those pathetic creatures who will eventually become wards of the state.

Another grave social problem is that of the unmarried mentally deficient girl who is promiscuous in her sex relationships and who becomes pregnant at frequent intervals. Sterilization of such an individual, with the permission of the parents and the juvenile court, is a desirable thing both from the standpoint of the family of such a girl and for the welfare of the community.

Amaurotic family idiocy is a rare condition that is prone to recur in certain families. If this condition is found in the offspring of one woman more than one time, that patient is entitled to sterilization in order to protect her from the danger of bringing more such infants into the world.

Neuro-psychiatric Indications: In some states there is a law making sterilization of the insane compulsory. It is definitely known that certain types of insanity have a tendency to recur in the offspring of the person afflicted. Many of these patients have recessions of their mental conditions, but if during such a period of betterment of condition that woman becomes pregnant there is likely to be a relapse of great severity. Therefore sterilization of such a patient is desirable both because of the good it may do the patient and because of the reduction in the numbers of the potentially insane.

Certain women, otherwise absolutely sane, develop a true psychosis during the course of a pregnancy. These patients have an absolute clearing of symptoms after the termination of the first pregnancy in which the condition developed, but with subsequent pregnancy the mental upset becomes worse and of longer duration. Such a patient should not be allowed to go through more than one pregnancy because of the danger of a permanent return of the previously encountered mental condition. We also see cases of puerperal psychosis in patients who go through their pregnancies and labors normally but during the course of the puerperium develop a psychosis. The majority of these women recover eventually, but to allow such a patient to again become pregnant is not good judgment inasmuch as she may develop a more severe and more permanent psychosis during her next puerperal period. Sterilization of women in this group is strongly advocated.

Chorea gravidarum, a very severe neurological condition that occurs in the course of pregnancy, is very likely to again appear during the next period of gestation in a more severe form. The choreiform movements may become so violent that the patient cannot control herself sufficiently to maintain her equilibrium. Falls are very frequent during these attacks and at times there are such severe injuries resulting from these falls that the patient is permanently crippled or dies. There are also cases reported where the movements were so violent and of such constant character as to completely exhaust the system and end in death from cardiac failure. Inasmuch as this condition is likely to recur during subsequent pregnancies, it is safest to sterilize the patient after the termination of the first pregnancy in which the chorea was observed.

True epilepsy is another indication for sterilization both because the patient herself is endangered and because the disease may be transmitted to the offspring. The danger of the patient lies

in the direction of increasing the severity of the epilepsy. It is known that the siezures are of more frequent occurrence and of greater severity during the course of a gestation, and following multiple pregnancies there may be a permanent change for the worse in the condition of the individual. Although the transmission of epilepsy to the offspring may be debatable there can be no question that if a mother with this condition has a child who shows an epileptic tendency, that woman should be sterilized in order to prevent her bringing more of her kind into being.

The rare neuromuscular conditions, pseudo-hypertrophic muscular dystrophy, progressive muscular atrophy, and myasthenia gravis are all characterized by a muscular weakness. If a patient with any one of these diseases becomes pregnant and extra weight is added to that which the weakened muscles must support, the general condition of that patient will suffer and the muscular condition will become aggravated because of the added strain. If patients suffering from these conditions are sterilized and the possibility of pregnancy is removed, the treatment of the neuromuscular disease can proceed without interruption.

THERAPEUTIC ABORTION

Unfortunately, many of the patients suffering from these conditions do not present themselves for examination until after pregnancy has taken place. Our problem now is twofold, doing away with the pregnancy and sterilizing the patient in order to obviate the possibility of future pregnancy. But even this double problem need not be difficult. In employing the vaginal route of operation the therapeutic abortion can be done as a part of the sterilization operation without adding much to the technical difficulties of the procedure. In doing the combined sterilization and abortion we prefer to do a fundal vaginal hysterotomy instead of the traditional transcervical uterine evacuation. In doing the operation by this method we do not go through the frequently infected cervix and so cut down on the chance for postoperative infection. In following out this technique we do not encounter sepsis such as we see on occasion in the patients who have had pregnancy terminated by the transcervical approach.

OPERATIVE TECHNIQUE

Sterilization can always be accomplished by the use of radium or the *x*-ray, but we rarely employ these methods of procedure because of the disadvantages attendant on their use. The *x*-ray and radium sterilize by a destruction of the ovarian function. This means that the patient will be thrown into the menopause, and menstruation will cease. In many patients the cessation of menses will prove a damaging psychic factor, while in others the symptoms accompanying the menopause may be very severe. Therefore we advocate the use of these forms of sterilization only in women who are approaching the age of the menopause or in those who have such serious medical conditions as to make even the very simple vaginal operation dangerous.

It must be remembered that in the course of the operation the abdomen is opened through the vagina and we must be very particular about the preoperative preparation of these patients. The external genitals and vaginal tube should be thoroughly washed with tincture of green soap and sterile water three times, with great care to get up to and behind the cervix. The soap is washed out with sterile water or with 1:5000 bichloride of mercury solution. The vagina is then thoroughly saturated with one-half strength tincture of iodine or the surgical preparation of mercurochrome, special attention being given to the posterior vaginal vault and the cervix. When the cervix is brought into view it is again swabbed with the iodine. These simple precautions will go a long way toward reducing to an absolute

minimum the chances of postoperative infection.

We will describe the technique that we use for simple vaginal sterilization, that for the repair of cystocele in conjunction with the sterilization, and that for the performance of therapeutic abortion during the course of the sterilization operation.

Simple Sterilization: The perineum is held back by the use of a weighted vaginal retractor. The anterior and posterior lips of the cervix are grasped by single tooth volsella tenaculae, and the uterus is pulled down into the vagina. Two cubic centimeters of obstetrical pituitrin are injected into the cervical tissues in order to promote uterine contraction as well as generalized contraction of the pelvic vessels and so cut down on the amount of bleeding encountered during the course of the operation. An incision is made across the anterior lip of the cervix (Fig. 1) just below the insertion of the bladder on the uterine wall. This incision is carried through the vaginal mucosa and submucous fascias. These fascias are then separated from the uterine wall, from side to side and upward by means of sharp dissection. A plane of cleavage will soon be found which will enable one to strip the bladder and its attached mucosa from the anterior wall of the uterus by gentle pressure with the gauze-covered finger. This separation of the bladder from the uterus is carried up to the point where the peritoneal reflection is brought into view. A narrow anterior retractor is now inserted between the reflected bladder and the uterine wall, and traction on this retractor gives one a good view of the peritoneum. The peritoneum is now incised and this incision is widened by inserting both index fingers and pulling them apart. This brings the fundus of the uterus into view and the anterior retractor is now placed between the upper peritoneal flap and the uterus (Fig. 2). The cervix is now pushed backward into the posterior vault of the vagina and in this manner the fundus is forced down toward the vaginal opening. The uterus is now grasped with a single toothed volsellum forceps, and by gentle traction is delivered into the vagina. This brings into view the entire uterine body together with the tubes and their insertions in the cornua.

The tube is grasped with a hemostatic forceps about ½ inch from the uterine horn and cut across. This incision is carried parallel to the tube as far as the uterine horn and across this, removing with it the interstitial portion of the tube (Fig. 3A). The uterine horn is now closed by a continuous running suture of chromicized catgut interlocked every second or third stitch (Fig. 3B). Care must be taken to bury the cut end of the interstitial portion of the tube. The proximal end of the cut tube is then brought over this portion of the uterine horn and sutured. In sewing the tube and its broad ligament attachment to the uterus care is taken to go around instead of through the tube. Thus we are peritonizing the raw edges of the uterine cornua and at the same time each stitch is surrounding and constricting the tube so that maintenance or reestablishment of the patent lumen is impossible. The same procedure is carried out on the other side (Fig. 4B). In the large series of cases in which we have employed this operation we are not aware of a single instance in which it has failed to sterilize permanently.

The uterus is now replaced in the abdominal cavity and the anterior retractor is taken out from beneath the peritoneal flap and reinserted beneath the bladder. The index finger is put into the abdominal cavity and the peritoneal edge is found and secured by a suture. The peritoneum is closed by several interrupted sutures of catgut. The anterior retractor is now removed and the bladder together with the attached mucosa is pulled down into place. The vaginal mucosa is now closed by interrupted sutures of chromic catgut.

Sterilization with Repair of Cystocele: If cystocele is present and operative treatment is decided upon in conjunction

with the sterilization, the technique is somewhat varied. In these cases it is necessary to separate the bladder from the vaginal mucosa at the outset and then to separate the bladder from the uterine wall. The same primary incision is made through the vaginal mucosa and then a curved rounded tip scissors is insinuated between the vaginal mucosa and the bladder. After pushing the scissors as high as possible it is opened and in this manner the bladder is separated from the vaginal mucosa. The mucosa is now split up the mid line as far as the separation has been completed, and in repeating the process the division of layers is carried on as high as the urethra. Lateral separation of the mucosal flaps is very readily carried on by gentle pressure with the gauze-covered finger.

The bladder is now separated from the anterior uterine wall as previously described, and the sterilization operation is carried out. After the sterilization is completed and the peritoneum is closed we proceed with the repair of the cystocele.

The vaginal mucosa is trimmed in order to tighten the covering of the bladder when the repair is completed. The lower edge of the bladder fascia is now caught and sutured to the uterine wall 1½ to 2 inches higher than its previous insertion. This elevates the bladder on the uterus and prevents it from coming lower down on the cervix. The bladder is sutured to the uterus with three interrupted sutures, one in the mid line and one on either side. The subpubic fascias are now brought together from side to side. This tightens the urethra and acts as a support for both it and the bladder. The vaginal mucosa is now brought together in the mid line by a continuous interlocked suture of chromic catgut starting near the urethra and proceeding downward. When a point below the newly made insertion of the bladder is reached, the suture is brought through one side of the vaginal mucosa, through the uterine musculature, and then through the other side of the vaginal mucosa. This type of stitch is carried on down to the lower edge of the vaginal incision. By taking these bites through the uterine wall we form another barrier in the path of the bladder should there be a tendency for it to slide down, preventing such a possibility and at the same time eliminating any "dead space" that may exist between the wall of the uterus and the vaginal mucosa. The transverse incision across the cervix is closed by several interrupted chromic catgut sutures. A retention catheter is put in place and left for five to seven days in order that the bladder may be kept empty during this time. This emptiness of the bladder allows it to regain its muscular tone and shrink in size. Thus, with increased bladder tonus, there will not be a tendency for over-distention and the primary causative factor in cystocele is removed.

Sterilization with Therapeutic Abortion: If therapeutic abortion is to be performed in conjunction with the sterilization the technique is not varied until the uterus is delivered into the vagina. A transverse incision is made across the fundus of the uterus anteroposteriorly (Fig. 5). The incision can be made from side to side and carried on to the removal of the uterine cornua, but we prefer the anteroposterior incision because in the mid line of the uterus no major vessels or large branches of these vessels need be cut across and the operation is practically bloodless. When the uterine cavity is opened into the products of conception can be squeezed through the incision in toto. The decidua is lightly curetted out through the incision and all is very carefully sponged away in order to prevent the possible development of an endometriosis. The incision in the uterus is closed by a running suture of chromic catgut, and this in turn is covered by a serosal stitch of fine plain catgut for purposes of peritonization. The sterilization operation is now carried out and completed as described.

[For Conclusions see p. 539.]

RUPTURE OF A CORPUS LUTEUM

WITH INTRA-ABDOMINAL HEMORRHAGE SUBSEQUENT TO ACUTE APPENDICITIS

R. B. McKNIGHT, M.D., F.A.C.S.

CHARLOTTE, N. C.

RUPTURE of a graafian follicle or corpus luteum cyst with severe hemorrhage occurs infrequently enough to warrant report. From the scattered single case reports, it seems probable that this condition occurs more frequently than is generally supposed. There is evidence that in some such cases bleeding has ceased spontaneously. The literature has been recently reviewed by Johnson[4] and by Greenhill[3] and discussions of the physiology, pathology, symptoms, diagnosis and treatment have been presented.

Recently a patient came under my care who presented the bedside picture, first, of an acute appendicitis, and, later, that of a ruptured right ectopic pregnancy:

A white matron, twenty-eight years old, was admitted to the Mercy Hospital shortly after midnight, January 25, complaining of severe lower abdominal pain, marked shoulder-top pain, collapse and shock. The menstruation was always regular and normal. At the birth of her child, seven years previously, labor was difficult. There had been no other pregnancies.

The morning before admission she went to her doctor complaining of moderate generalized abdominal pain of several hours' duration. He found some tenderness and rigidity over the right lower abdominal quadrant, and, on pelvic examination, a cyst of the right ovary the size of a walnut. The patient was advised to go home and to bed; symptomatic treatment was prescribed and a policy of watchful waiting assumed. Later in the evening her pain increased and localized in the right lower abdominal quadrant and nausea and vomiting came on. He then made a diagnosis of acute appendicitis and advised surgical relief. As she got into her car she experienced a sudden stabbing pain in the lower right abdomen, this in addition to the pain for which she sought relief. During the 25 mile ride to Charlotte, she complained of about as much right shoulder-top pain as abdominal. On admission her doctor said he thought she was suffering from an acute appendicitis, that there was an ovarian cyst present, and if the abdomen were opened he wanted the gall-bladder examined on account of the shoulder pain.

The patient was acutely ill. Blood pressure was 100/68, pulse 114, weak and of poor volume, temperature 99.4°F., respirations 24. There was an anxious expression on her face. The chest was entirely negative. The abdomen was tender and painful throughout, especially in the right lower quadrant, where there was also definite rigidity. A distinct fluid wave could be elicited. There was fluctuation in both fornices with marked tenderness on the right. The urine contained a trace of albumin and an occasional pus and blood cell; hemoglobin was 80 per cent, leucocytes 14,600.

We then made a diagnosis of ruptured ectopic pregnancy and, under nitrous oxide-ether anesthesia, opened the abdomen through a right rectus incision. On exposing the peritoneum, blood was seen underneath. The abdominal cavity contained 500 c.c. of fresh blood which was removed by suction, but kept accumulating. A quick examination revealed normal tubes and a typical acutely inflamed appendix. It was thought best to remove the appendix rapidly and then search for the source of the hemorrhage. The bleeding was found to come from a ruptured corpus luteum of the right ovary, in the depths of which was a small spurting artery. The area was resected by making a v-shaped incision and suturing in the usual manner. Sufficient peritoneal toilet was done and the abdomen closed without drainage. She stood the operation only fairly well and was not in good condition at its completion. After intravenous saline and glucose and supportive treatment, she rallied and blood transfusion was not necessary. Her convalescence was uneventful and she was dismissed from the hospital the thirteenth day after operation.

DISCUSSION

This case is of especial interest from the viewpoint of diagnosis. With definite evidence of bleeding and a distinct fluid wave, the diagnosis of acute appendicitis naturally gave way to that of ruptured ectopic pregnancy. Right shoulder pain makes one think of possible gall-bladder disease. However, the referred pain of biliary disease is to the right subscapular region, to the midline between the scapulae, or even to the left subscapular: it is not shoulder-top. Cope[2] believes that shoulder-top pain in the presence of lower abdominal symptoms establishes a diagnosis of ruptured graafian follicle or corpus luteum; perhaps the same symptoms occur in ruptured ectopic pregnancy.

Another feature of this case is one brought out by Brakeley and Farr.[1] In studying the cases reported, in all but one they observed rupture occurred during the week preceding the onset of the menstrual period. This was true of the case under discussion. Her period began three days after operation and she stated that it was her regular time.

Undoubtedly rupture occurred when she was getting into the car, as it was then she had the sudden stabbing pain and shortly afterwards pain was felt in the shoulder tops. Had the referring physician gone a step further he would have made a diagnosis which is seldom made, that of a ruptured corpus luteum with intra-abdominal hemorrhage, immediately preceded by an attack of acute appendicitis. The usual preoperative diagnosis in ruptured corpus luteum is either acute appendicitis or ruptured tubal gestation. In the words of the late John B. Deaver: "the aseptic scalpel dispelled doubt and revealed the truth—the whole truth!" Practically all of these cases will be diagnosed after the abdomen is opened; if we are alert we can make more correct diagnoses with the abdomen unopened. One can at least be sure that there is an intra-abdominal lesion demanding immediate surgical intervention.

REFERENCES

1. Brakeley, E., and Farr, C. E. Ruptured graafian follicle or corpus luteum cyst simulating acute appendicitis. *Am. J. M. Sc.*, 172: 580–585, 1926.
2. Cope, V. Z. Some neglected symptoms in acute abdominal disease. *Brit. M. J.*, July 18, 1931.
3. Greenhill, J. P. Rupture of a corpus luteum with intraabdominal hemorrhage. Report of three cases. *Am. J. Obst. & Gynec.*, 22: 902–906, 1931.
4. Johnson, V. E. Acute hemorrhage from corpus luteum and graafian follicle. Am. J. Surg., n.s. 9: 538–544, 1930.

CONCLUSIONS OF DR. KANTER & DR. KLAWANS*

1. Sterilization of a woman is often necessary in order to save or to prolong the life of the patient.

2. Definite indications for sterilization exist, and the duty of the physician is to recognize these indications at the earliest possible time.

3. The use of contraceptives as a permanent method of sterilization is futile due to their frequent failure.

4. The vaginal route for the operative procedure has many distinct advantages over the abdominal approach.

5. Vaginal plastic operations and therapeutic abortion can be carried out as a part of the sterilization operation.

6. The indications for sterilization are given. They are divided into the following classes: cardiac, renal, pulmonary, otolaryngological, local anatomical, social, and neuropsychiatric indications.

7. The fundal hysterotomy for therapeutic abortion is preferred over the transcervical route.

8. The operative techniques for vaginal sterilization, vaginal sterilization combined with cystocele repair, and vaginal sterilization with therapeutic abortion are described in detail.

*Continued from page 537.

A SIMPLE METHOD OF

SUPRAPUBIC CYSTOSTOMY

NORVELL BELT, M.D.

WASHINGTON, D. C.

NUMEROUS methods of opening a bladder by the suprapubic route have been devised with an attempt to speed technique on patients where time is especially important. The following is presented because of its simplicity.

The bladder is exposed in the usual manner and the site of puncture selected. An ordinary operating scalpel is introduced through one of the fenestra of the suprapubic catheter, penetrating the tip as far as the hilt. The mushroom is obliterated by traction on tube and bladder wall retracted with forceps. Knife blade with tube attached is inserted. The viscus must be thoroughly distended to prevent intravesical trauma. Withdrawal of the blade flattens the mushroom and the catheter remains within the bladder. Sutures are placed and closure completes the operation.

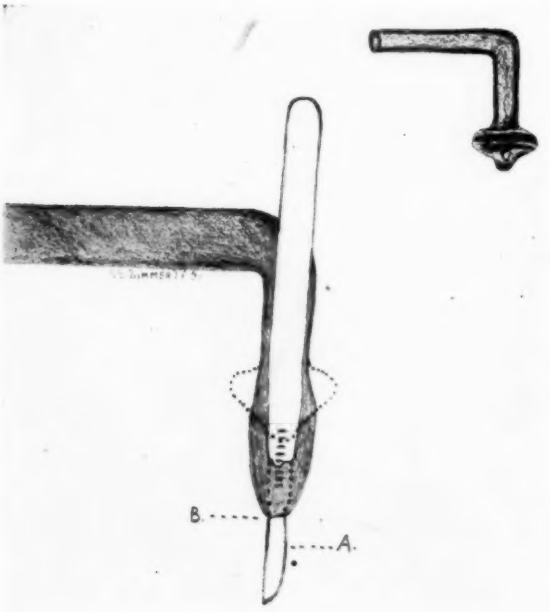


FIG. 1. A, Knife blade has pierced tip of catheter. B, Impinging hilt acts as obturator in obliterating mushroom. Inset shows ordinary mushroom catheter.

This procedure does away with special instruments and minimizes the flooding of the operative field which hampers closure. Shock is lessened by shortening of the operating time.

A COMFORTABLE AND SANITARY COLOSTOMY BAG*

E. R. ARN, M.D., F.A.C.S.

DAYTON, OHIO

THE need for a mechanically simple, comfortable and sanitary colostomy bag is apparent. Many of the colostomy outfits now available are complicated, provide a source of discomfort to the patient and are most difficult to keep clean. The purpose of this communication is to describe a colostomy outfit which overcomes all of these difficulties.

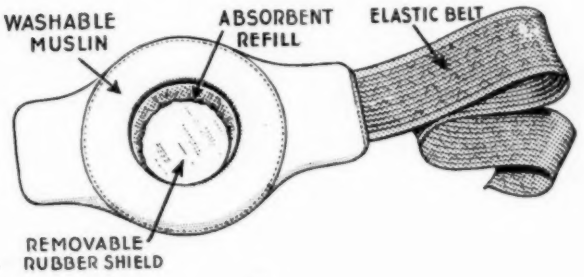


FIG. 1.

Mr. E. D. Smith, Plant Engineer of the National Cash Register Company, of Dayton, Ohio, was subjected to colostomy two years ago. Mr. Smith experimented with all of the available colostomy outfits. His dissatisfaction resulted in the invention of the colostomy outfit which bears his name and is now procurable through trade channels.

The Smith Colostomy Outfit contains no metal parts. The bag proper is made of washable muslin, on the inside of which is placed a removable sheet rubber shield. A removable cellucotton refill is placed inside the muslin ring. One or two small squares of gauze are then placed at the bottom of the bag in the space in the center of the absorbent refill. The bag is then held firmly in place by a wide elastic belt. If any part of the bag should become soiled the entire outfit may be readily washed. The patients who have used this outfit during the past two years are enthusiastic over its advantages.

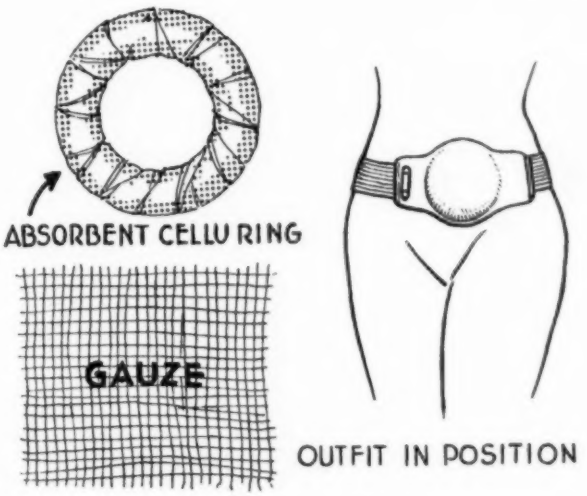


FIG. 2.

* From the Surgical Division of the Dayton Clinic, Dayton, Ohio.

The American Journal of Surgery

Editor: THURSTON SCOTT WELTON, M.D., F.A.C.S., NEW YORK

Editor, Department of Radiology: JAMES T. CASE, M.D., F.A.C.S., CHICAGO

EDITORIAL BOARD

WALTER C. ALVAREZ, *Rochester, Minn.*; DONALD C. BALFOUR, *Rochester, Minn.*; CARL BECK, *Chicago*; ALEXIS CARREL, *N.Y.*; ROBERT C. COFFEY, *Portland, Ore.*; ISIDORE COHN, *N.O.*; W. B. COLEY, *N.Y.*; FREDERICK A. COLLER, *Ann Arbor*; GEORGE W. CRILE, *Clev.*; ELLIOTT C. CUTLER, *Clev.*; ROBERT V. DAY, *Los Angeles*; CHARLES A. ELSBERG, *N.Y.*; C. R. G. FORRESTER, *Chicago*; H. DAWSON FURNISS, *N.Y.*; JOHN H. GIBBON, *Phila.*; EMIL GOETSCH, *Brooklyn*; DONALD GUTHRIE, *Sayre, Pa.*; A. E. HERTZLER, *Kansas City*; C. GORDON HEYD, *N.Y.*; LOUIS J. HIRSCHMAN, *Detroit*; JAMES M. HITZROT, *N.Y.*; EMILE F. HOLMAN, *San Francisco*; REGINALD H. JACKSON, *Madison*; JOHN E. JENNINGS, *Brooklyn*; WM. L. KELLER, *Washington*; HOWARD A. KELLY, *Baltimore*; ARTHUR KRIDA, *N.Y.*; A. V. S. LAMBERT, *N.Y.*; H. H. M. LYLE, *N.Y.*; JEROME M. LYNCH, *N.Y.*; URBAN MAES, *N.O.*; ROY D. MCCLURE, *Detroit*; J. TATE MASON, *Seattle*; RUDOLPH MATAS, *N.O.*; H. C. NAFFZIGER, *San Francisco*; E. W. ALTON OCHSNER, *N.O.*; CLARENCE R. O'CROWLEY, *Newark, N.J.*; F. R. PACKARD, *Phila.*; LOUIS E. PHANEUF, *Boston*; E. H. POOL, *N.Y.*; DOUGLAS QUICK, *N.Y.*; HUBERT A. ROYSTER, *Raleigh*; A. C. SCOTT, *Temple, Tex.*; M. G. SEELIG, *St. Louis*; J. BENTLEY SQUIER, *N.Y.*; JOHN E. SUMMERS, *Omaha*; GEORGE W. SWIFT, *Seattle*; J. M. WAINWRIGHT, *Scranton*; GRANT E. WARD, *Balt.*; F. C. WARNSHUIS, *Grand Rapids*; ALLEN O. WHIPPLE, *N.Y.*; J. HOMER WOOLSEY, *San Francisco*.

Foreign Collaborators—GREAT BRITAIN—J. JOHNSTON ABRAHAM, *London*; E. F. FINCH, *Sheffield*; ANDREW FULLERTON, *Belfast*; BASIL HUGHES, *Bradford*; GEOFFREY JEFFERSON, *Manchester*; SIR ROBERT JONES, *Liverpool*; R. E. KELLY, *Liverpool*; G. P. MILLS, *Birmingham*; C. MAX PAGE, *London*; S. S. PRINGLE, *Dublin*; J. J. M. SHAW, *Edinburgh*; H. S. SOUTTAR, *London*; J. H. WATSON, *Burnley*.
FRANCE—G. JEANNENEY, *Bordeaux*. ITALY—RAFFAELE BASTIANELLI, *Rome*.

The American Journal of Surgery is truly independent and enters into no "entangling alliances." It publishes many papers read before the leading surgical societies of the Country, but it is *not* "the official organ" of any organization. Every manuscript is selected by the editors as worthy of publication—nothing is published merely because "it was read at the meeting."

EDITORIALS

ASPHYXIAL DEATH—A PROFESSIONAL DISGRACE*

THE death rate from asphyxia is a reproach to the practitioner of medicine; first, because of figures available from municipal vital statistics; secondly, because the medical profession has practically turned over the treatment of asphyxia to a non-medical personnel.

The death-rate from asphyxia drawn from vital statistics of the City of New York for the year 1931 with a total registered population of 7,090,099 is more than twice the death-rate for auto accidents, 18 times the death-rate for diphtheria, and almost 40 times the death-rate reported for typhoid.

The argument may be advanced that we all die of asphyxia. The test of true asphyxial death, however, readily disposes of this contention. The generally accepted immediate treatment of asphyxia neonatorum, illuminating gas, submersion, anesthetic accidents, etc. is removal of the obstruction to the respiration and the application of artificial respiration. Prompt and efficient treatment along these lines usually results in cure. Failure to apply such treatment results in death from asphyxia.

In previous communications[1] the author has pointed out the fact that asphyxia is a generic condition, the specific instances of which are found in the various etiological factors listed below:

The segregation of various types of asphyxia, all subject to the same essential

[1] *Arch. Otolaryng.*, July, 1930; *Am. J. Obst. & Gynec.*, April, 1931; AM. J. SURG., 8: No. 6, 1930.

* A solution to the problem outlined above will be discussed in an editorial by Dr. Flagg in the next issue.

form of treatment, is the reason for the astonishing figure disclosed.

The following figures are on file in the Bureau of Vital Statistics, City of New York; for the year 1931, the total population then being reported as 7,090,086:

Submersion	442
Lightning	0
Electric shock	25
Drugs	0
Anaesthesia	42
Illuminating gas	305
Other gases	28
Mechanical suffocation	33
Conflagration	59
Total	954

It is fair to assume that the report of drug deaths and the report of anesthetic deaths are underestimated. Foreign body obstruction does not appear as such.

Of the total number of stillbirths reported (5579), the following may be classed as capable of response to resuscitation properly applied:

Cord pressure	535
Breach	140
Malposition	91
Deformed pelvis	91
Difficult labor	279
Asphyxia	282
Total	1418

If we reduce this figure by one third to allow for unavoidable deaths, we have a total of 946.

Antenatal and postnatal atelectasis results in asphyxial death, and may be treated and relieved, as is any other form of asphyxia, by intratracheal insufflation, under measured pressure.

The figure given for atelectasis (672) is not exclusive, as it includes icterus, sclerema, etc. For the sake of being conservative, we may reduce this figure one half, and accept a total of 336.

Pulmonary complications occurring during the first month may be regarded as due, in part, to aspiration pneumonia following birth, consequent upon a failure to remove fluid from the baby's pharynx and trachea. The figures for lobar pneumonia are 55; for bronchopneumonia, 181; allowing one third for pneumonia from other causes, we have a total of 158.

Premature infants dying in the first day frequently lose their lives from inefficient means of resuscitation. The total figure is 852. Allowing 50 per cent off of this figure, we have 426.

The totals of the various types of asphyxia are, therefore, as follows:

General asphyxia	934
Stillbirth	946
Atelectasis	336
Pulmonary complication	158
Premature	426
Total	2800

Comparative figures from various causes of death are as follows:

Death from	
Typhoid	77
Diphtheria	156
Auto accidents	1298
Asphyxia	2800

If it be advanced that many asphyxial deaths, such as from submersion, lightning, conflagration, etc. are quite outside the possibility of rescue, it should also be recalled that many auto deaths are in the same category.

Why, it may be asked, was this situation not known long ago? The answer lies in the segregation of the specific instances of asphyxia into a single group, responding to a common treatment.

Why, it may be asked, has the Medical Profession been so remiss in its care of these patients? The reason is, that until within the last three years, no medical technique, or armamentarium suitable for the use of a physician was available.

The problem before us is a significant one from an economic point of view. Based upon a capital value of $5,000 for a life, we have a capital loss of $14,000,000. for New York City alone; or, or a quarter of a billion dollars for the United States with a population of 125,000,000.

Much of this life and much of this economic value may be saved by acknowledging the problem before the nation.

Approximately two-thirds of these lives are newborn; physically well when rescued. Would it not be worth every effort that we could make to preserve these to posterity?

Paluel J. Flagg, M.D.

AMERICAN PHYSICIANS

THOMAS CADWALADER

THOMAS CADWALADER of Philadelphia was born in 1708. Properly, he belongs in that group of medical giants who were responsible for Philadelphia becoming an important medical center.

While he was yet a youth (eighteen or nineteen years old) his father sent him abroad to complete his medical education. On his return to Philadelphia he soon won favor and acquired a remunerative practice. We are told that upon his return from Europe, Cadwalader "made dissections and demonstrations for the instruction of the elder Dr. Shippen and some others who had not been abroad." Wistar says the place these instructions were given "was in a building on the back part of a lot, on which the Bank of Pennsylvania now stands."

After his marriage (1738) to Hannah Lambert of New Jersey, he spent a great part of his time for several years in that state near Trenton, returning to Philadelphia about 1750.

With Franklin he was one of the founders of the Philadelphia Library. He was one of the American pioneers to adopt and practice the method of inoculation as a preventive against smallpox.

One of the high lights of his career is that he performed an autopsy in 1742. It is claimed to have been the first scientific autopsy performed in this country.

Cadwalader was one of the founders of the Pennsylvania Hospital. Also, he was a trustee of the Academy and College of Philadelphia. He was one of the charter members of the Philadelphia Medical Society. When the American Society for Promoting Useful Knowledge was consolidated with the American Philosophical Society (Franklin was President) in 1768, Cadwalader was the first named of three vice-presidents.

His services during the Revolution seem to have been those requested of him by Congress, and in assisting his friend, Dr. Morgan, at that time director-general of the military hospitals.

Only one publication bears his name: "An Essay on the West India Dry Gripes, to which is added an extraordinary case in physics. Philadelphia. Printed and sold by Benjamin Franklin, MDCCXLV." It is said to be one of the earliest medical monographs published in America.

Thomas Cadwalader died November 14, 1779, in Philadelphia.

T. S. W.

THOMAS CADWALADER

[1708-1779]

The American Journal of Surgery
N.S. Vol. XVIII. December. 1932

[From Fernelius' Universa Medicina, Geneva, 1679.]

BOOKSHELF BROWSING

BOUND FEET IN CHINA

F. M. Al-Akl, M.D.

NEW YORK

FOOTBINDING of Chinese females, a practice that fortunately seems to be rapidly disappearing from many of the Eastern provinces of China, is still rather prevalent in the country's interior, where the number of better educated females is too insignificant to exert any influence upon the communities in which they live, and where the inhabitants have hardly any contact with foreigners or foreign civilizations. Should China, however, keep up its present pace of progress, the custom in another century or so will inevitably become nothing more than one of the sad reminiscences of an agitated and tumultuous past.

The practice, which may possibly date much earlier, is believed to have been started by the Empress Taki about the year 1100 B.C. Having been born with club-feet, the Empress is said to have issued an order, on ascending the throne, exacting the binding of all female children's feet living in her domain, so they might thereby aquire an appearance analogous to that of their sovereign. Thus the style is supposed to have begun, and in time came to be handed over from mother to daughter as a fashionable practice. Again, some say that Emperor Gangti, completely fascinated by the graces of his most favorite concubine, had her feet bound. When their size was reduced to what seemed to him the most pleasing proportions, he presented her with a pair of very small shoes upon whose soles was carved a lotus flower to decorate her tiny footprints. It is, however, the belief of many Chinese that the custom was initiated and propagated by a desire among men to encumber their females in walking, in the hope of limiting their freedom and in coercing them to stay at home. But even at that, the men seem to have had little success, as in time women learn how to hobble about, without minding much the difficulties encountered in attempting to balance the body on their deformed extremities. Their gait, however, changes considerably, becoming peculiarly stiff and non-elastic, simulating one of a person who tries to walk on his heels over a wet floor.

The evils of this operation seem to have been realized time and again in China, and various attempts have been made to abolish this practice, without much avail. As early as 1664 the Emperor passed a law prohibiting footbinding, but the unsuccessful result occasioned by the lack of cooperation on the part of the subjects led, after a trial of four years, to its amendment.

The binding usually begins between the ages of four and eight, most often about six or seven, after the child is thor-

Fig. 1.

oughly well able to walk, and is continued throughout the entire life of the individual. No periods of rest or intermission, not even an overnight's relaxation is allowed and the victim is eventually placed in her coffin with the bandages tight on her cold feet. So when the time comes, the mother, especially if she is young and inexperienced in binding a youngster's feet, or if she is afraid lest her sympathy should betray her at the sight of her own child's tears, she calls to her aid an older and more experienced neighbor or possibly her customary midwife. In the case of the very rich, the bandage material is of silk, though usually strips of ordinary native cotton cloth or pieces of imported muslin are employed, each measuring about 3 to 5 feet in length and from 2 to 3 inches in width, depending largely upon the size of the foot. The number of strips is determined by the amount of tension to be exerted, but two to four usually suffice for each foot. The cloth is ordinarily plain, sometimes oiled. No preliminary preparation is required, and after the foot is kneaded a little, the cruel strips of cloth are tightly bandaged on. More vigorous kneading however is done after the bandages are applied. So severe are the manipulations that a fractured bone or the dislocation of a joint may occur.

The procedure consists in first diminishing the size of the foot by flexing the toes down upon the sole around its long axis. This is accomplished by the primary circular bandage started on the dorsum and wrapped around from the inner to the outer border. The great toe is the only toe

Fig. 2.

left in its position of normal extension, though it inevitably becomes compressed with the rest of the foot. After the binding, the girl is made to walk in order to help re-establish circulation and, with tears in her eyes, the child attempts to help support her body on the tender feet by holding on to the furniture about the room. The bandage is applied for the first few times by the experienced neighbor until the mother aquires the technique herself. The constantly reducing size of the foot tends in the beginning to loosen the bandages quite rapidly, consequently they have to be changed about once every day.

The toes being successfully flexed to a position beneath the sole, which operation may take a year, the second step in the process is more vigorously undertaken. This consists in diminishing the length of the foot by flexing it upon itself, thus approximating its front half to the heel. For the purpose, a figure of eight bandage is applied which compresses in its anterior loop the front of the foot and the heel in its posterior one, bringing them as closely together as possible. Thus, in addition to the actual interference with the normal

growth of the bone, the length of the foot is diminished by exaggerating the height of the plantar arch; the resulting fold in the

Fig. 3.

integument of the sole may be 2 to 3 inches in depth. Once the foot has been reduced to somewhere near the desired form, the various layers of bandage are secured together by a number of interrupted sutures. The bandage is then left for several weeks or months without being changed or reapplied unless it becomes loose or wears off; or unless the odor becomes exceptionally offensive, in which case a bath becomes unavoidable (a poor woman may not take a bath in the course of a whole year); or, unless the excruciating pain caused by the excoriation of the skin is rendered intolerable. By the age of eleven or so, the girl usually (acquires the art of applying) her own bandage as she begins to appreciate tiny feet and boasts of her own if they look any smaller than those of her companions.

The anatomical changes that take place in the foot are quite obvious and distinct. Viewed from above, the foot presents the appearance of a closed fist with a slightly hyperextended thumb. The projecting distal heads of the metatarsal bones resemble the knuckles of the fist when viewed from the same angle. The foot is very small and may be 2 inches at its broadest diameter. The nail of the great toe is almost cylindrical from lateral pressure. The contour of the dorsum is acutely angular. The tarsal bones curve sharply downward; the metatarsals run in an almost perpendicular plane. The sole is about triangular in shape

Fig. 4.

with the apex of the triangle at the tip of the great toe and the base towards the heel. Due to the weight sustained in walking, certain broad callosities are to a greater or lesser degree noticeable on what is now the plantar surface of the flexed toes. A deep fold divides the foot transversely and the skin of the sole looks tough and corrugated. The heel scarcely projects backwards and instead of the heel, a projection is usually noticeable over the posterior border of the ankle joint due to a backward displacement of the astragalus. Besides this forcing backwards of the astragalus, dissection reveals the peculiar position which the os calcis acquires. Instead of lying almost horizontally with its long axis running anteroposteriorly, the bone is found to have

rotated into a nearly vertical position whereby its long axis becomes almost continuous with that of the tibia. Its posterior surface to which the tendo achillis is attached becomes the inferior surface on which the weight of the entire body is sustained. The other points of support on the plantar surface of the foot are usually the distal head of the first metatarsal bone and the once dorsal surface of the fourth and fifth phalanges.

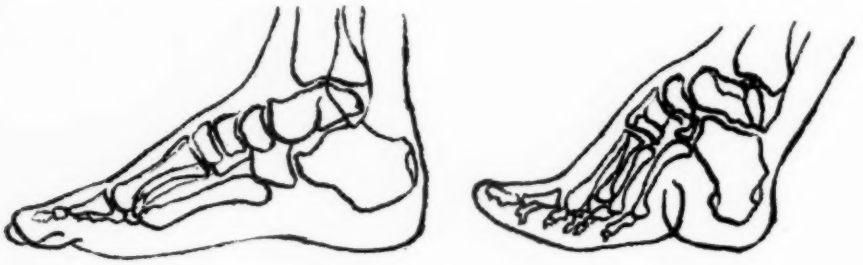


Fig. 5.

The pain resulting from the manipulations is terrific and the Chinese proverb which says "each bound foot costs a tubfull of tears" seems to be no exaggeration. The mother may often, in the beginning, take a stick along with her to bed to beat the child to sleep should she wake up and cry, or the child may be left in some shed outside the house for the first few nights in order not to disturb the rest of the household. Later on in life, the unbound foot becomes the painful one for, as the bandage is removed, the foot looses its habitual support and the contracted structures give rise to a great deal of pain under the stretching-out influence of the weight of the body. For this as well as for other reasons, the binding is kept up all through life, more so because any negligence for even a few days may allow the foot to regain somewhat its normal contour and form. Some people use wooden mallets to help reduce the foot to the desired shape, some go, though rarely, as far as extirpating the scaphoid in an attempt to properly fold up and rigidly pack the foot. In some sections of the country, those who can afford to, use a semi-cylindrical piece of metal inserted transversely in the plantar fold and bind the foot firmly to it. With such measures, an adult foot may come to measure as little as 2½ inches from the tip of the great toe to the edge of the heel. Should excoriations of the skin develop, the foot may be bathed in plain warm water and a dry bandage applied. No particular medicine is used despite the variety of applications ranging from powdered tiger's bones to mortar from the Great Wall which native medicine men prescribe. This probably may be due to the fact that women are very much ashamed to talk about their feet, more so to show them to any one. As a matter of fact, they would consent to subject their genitals to an examining physician much more willingly than they would their feet; thus an excoriation may quite commonly develop into an ulceration and necrosis of the skin. The latter is more apt to occur in cases where the binding has been started rather late in life, apparently because the readjustments in circulation are so much more difficult then. The atrophy of the muscles of the calf is marked and the women, unable to balance themselves on the deformed feet, may often be seen kneeling down to perform the various exigencies which require the erect position.

Where footbinding exists, it is prevalent among all classes of people, more so among the well-to-do than among the poor. The Chinese consider small feet the outstanding feature of aristocracy and their largeness the extreme of vulgarity and plebeianism. The size of the foot, besides, seems to constitute the chief criterion of a woman's

commercial value. For when the woman is taken in marriage, her money is paid in inverse proportion to the size of the shoe she wears. If the shoes are small, the wooer usually has to settle the account in silver, if large the deal may be concluded in coppers with the loss of so much profit to the parents. It was this state of affairs that had for so long agitated the French sisters of Charity who, realizing the difficulties girls with large feet have to contend with in trying to find a suitable husband, consented most unwillingly to the footbinding of their orphans and boarding students.

The Chinese must obviously see certain beauty in small feet, hence their appreciation and predilection. Not only does the attraction seem to depend upon the mere smallness of the size, but also upon the consequences and after developments. The shortened pace and the slightly swaying coquettish gait seem to hold their special fascination and grace; so much so that in certain Tartar provinces where footbinding is prohibited, women use a peculiar type of footwear where the heel, instead of being at the back of the shoe, is placed about the middle in order that the Mongolian woman may be able to imitate her Chinese sister's gait by balancing herself on this centrally located heel.

Apart from this, there seems to be a strong sexual factor accountable in part for the long persistence of footbinding. The resulting atrophy of the muscles of the calf and the hypertrophy of the thighs, hips and mons veneris in particular is said to give the body a peculiarly exciting form. This probably is the reason why prostitutes attend to their feet with such fastidiousness and form the habit of bringing them together and sitting down on them when they want to rest, thus augmenting the pressure on their packed feet by the weight of their bodies.

Despite the many condemnations and all that may be said against the practice of footbinding, there unquestionably is a certain amount of taste in the underlying idea. The Chinese poet who wrote: "A large foot is a disgrace" must have had his reason; and despite the tendency to exaggerate the diminution of the foot's size, the notion may have been dictated by good esthetic sense. Even among Westerners, the tendency is to make the foot look as small as possible; and many a foot has been compressed and toes jammed together to the point of over-riding inside the diverse forms of narrow pointed shoes. Then again, should the theory so often quoted that man and the monkey come from a common origin be true, the Chinese would be assisting nature in diminishing the size of a foot no longer used in grasping branches or climbing up trees. Not only does the binding diminish the size of the foot, but by exaggerating the plantar arch and erecting the os calsis, it increases the length of the entire leg. The woman's waist is thus raised and her legs aquire a more artistic proportion to her trunk; Chinese women being certainly much more in need of that correction than white women.

The ill-effects of binding sustained by the foot as well as the system in general are innumerable. The legs which develop a variable degree of external rotation are spread apart in walking and the slightest mis-step may result in a severe fall. Thus walking and particularly running are greatly interfered with, the latter becoming practically impossible. Defecation is rendered very tedious and trying, for the stabilization of the body in the squatting position becomes exhausting if not impossible without some kind of support. The loss of the springiness of the normal foot exposes the spine to jarring if any amount of hurry is attempted. In addition to the excruciating pain, the various inevitable complications resulting from interference with the circulation are horrifying. Excoriations of the skin are to a greater or lesser degree present in every case. These may develop under the merciless persistence of binding into ulcerations which unavoidably become infected. The infection may travel down to the mutilated tissues and osteomyelitis may spread

rapidly in the devitalized bone once it has set in. The interference with circulation may be complete, in which case gangrene of one or more toes occurs. The gangrene may be dry or wet and may spread to the rest of the foot which not uncommonly drops off. One or more complications of sepsis in the foot may set in and end the victim's life. The ulcers may undergo malignant degeneration; suppurative inguinal adenitis, metastatic abscesses, erysipelas and septicemia may bring about a fatal issue. Should the individual however survive all these, the anemia and devitalization occasioned by lack of outdoor life, proper exercise, fresh air and sunshine in addition to the loss of appetite due to the obnoxious odors the feet emit, are most inviting to tuberculous infection which is always lingering somewhere in the filthy and unhygienic atmospheres of dwelling places and of which 10 per cent of the Chinese poor die yearly.

I wish to express my appreciation to Dr. James H. Ingram of Peking, China, who has practiced for forty-five years in China, for consultation in the preparation of this paper, and to Lewis Thorne for the illustrations.

REFERENCES

1. Cooper, B. Anatomical description of the foot of a Chinese female. *Trans. Roy. Soc. London*, 1829, Vol. II.
2. Vincent, E. La Médecine en Chine, 1915.
3. Maxwell, J. P. The evils of Chinese footbinding. *China M. J.*, 30: No. 6, 1916.
4. Harvey, J. L. Chinese bound feet. *Am. J. Roentgenol. & Rad. Therap.*, 10: No. 11, 1923.

BOOK REVIEWS

MEN AGAINST DEATH. By Paul de Kruif, M.D. Harcourt, Brace & Co., 1932.

It seems a short time ago that we purchased de Kruif's "Microbe Hunters" and when we had finished reading it made the wish that without loss of time he would write another book about physicians and scientists, laboratories, test-tubes, mice, guinea-pigs, grim death and great discoveries. We doubted that he would write another book that would be as absorbing and as interesting as the one we had just finished. But in "Men against Death" the author not only has duplicated his earlier feat but many will think he has outdone it.

For here is a book that is more exciting than most best selling novels. The lay mind will be intrigued; the physician will get a thrill. In addition he will learn much. He will learn the true recital of how many discoveries were really made.

In "Men against Death" the Prologue is entitled, "How Long Can We Live." And then, in their order, we become entranced with Semmelweis, a tragic man who found a safe way to help mothers have their babies; Banting, of insulin fame; Minot, who tricked pernicious anemia; Spencer, who found an unprecedented and fantastic way to guard men from spotted fever (thrilling); Evans, who removed one great danger lurking in the American milk supply; McCoy, who fought parrot fever (a general who didn't want to die in bed); Schaudinn, who discovered the pale horror of syphilis; Bordet, who spotted the pale horror's hiding; Wagner-Jauregg, and his friendly fever; Finsen, the Dane who trapped the light of the sun; Rollier, well known for his sun therapy, especially in the treatment of tuberculosis; and Strandberg, who turned Finsen's machine-sun on tuberculosis' most desperate consequence.

A fine book. Any physician who wishes to be thrilled, entertained and receive additions to his fund of knowledge will do well to own this book.

THE CURATIVE VALUE OF LIGHT, SUNLIGHT AND SUN-LAMP IN HEALTH AND DISEASE. By Edgar Mayer, M.D., F.A.C.P., N. Y., D. Appleton & Co., 1932.

So much has been published on the subject of heliotherapy, much of it in the lay press, that it is well to have a popular book by such an authority on this subject as Dr. Edgar Mayer of Saranac Lake. The subject is discussed in a common sense fashion and the pros and cons of advanced methods of light treatment are discussed in concise yet thorough manner. While written essentially for the layman, the book will be found of interest to any medical man.

THE CARDIAC OUTPUT OF MAN IN HEALTH AND DISEASE. By Arthur Grollman, PH.D., M.D. Springfield, Ill., Charles C. Thomas, 1932.

This is a scientific monograph on the cardiac output of man which will be found of great value to the specialist and undoubtedly many physicians and surgeons will profit by a thorough study of this subject. The book is well written, easy to read and thoroughly understandable.

A THOUSAND MARRIAGES. By Robert Latou Dickinson and Laura Beam. With an Introduction by Havelock Ellis. Balt., Williams & Wilkins Co., 1932.

A Thousand Marriages was prepared under the auspices of The National Committee on Maternal Health. It is a medical study of sex adjustment; the first considerable medical analysis of marriage in its widely human relationship. In this study, we are told, the source-material came from the extensive case-histories of a distinguished gynecologist, some of which extended over a period of thirty-five or forty years. After carefully reading this work we agree with the statement that "it is by no means narrowly confined to physiological aspects. The approach was gynecological but the presentation of the whole situation, physical and psychic, is most comprehensive and searching, sane in its recognition of the facts, wise and tolerant in its attitude."

To physicians who are interested in problems of sex, whose work brings them within the borders of this subject, to gynecologists and obstetricians who feel they should go beyond the rigid borders of their specialities and iron out the sex problems of their patients, for a better and broader understanding of this subject, this book is recommended.

BOOKS RECEIVED

All books received by THE AMERICAN JOURNAL OF SURGERY are listed in this column as soon as possible after their receipt and this must be considered as adequate acknowledgement. Books that the Editor considers of special interest to our readers will be reviewed in a later issue.

ADVANCE OF MEDICINE (THE). By Lord Moynihan. Lond., Oxford Univ. Press, 1932.

ARZT UND SEINEN KRANKEN (VOM). By Albert Krecke. Munich, J. F. Lehmanns, 1932.

CHILDRENS TONSILS, IN OR OUT. By A. D. Kaiser, M.D. Phila., J. B. Lippincott, 1932.

CLINICAL GYNECOLOGY. By C. Jeff Miller, M.D. St. Louis, C. V. Mosby, 1932.

COLON, RECTUM AND ANUS (THE). By Fred W. Rankin, M.D., J. Arnold Bargen, M.D. and Louis A. Buie, M.D. Phila., W. B. Saunders, 1932.

DIAGNOSIS AND TREATMENT OF DISEASES OF THE THYROID GLAND. By George Crile, M.D. Phila., W. B. Saunders, 1932.

DISEASES OF THE NOSE, THROAT AND EAR. Ed. 3, by A. Logan Turner, M.D. N. Y., Wm. Wood, 1932.

DISEASES OF THE THYROID GLAND. By Cecil A. Joll, M.D. St. Louis, C. V. Mosby, 1932.

EARLY DIAGNOSIS OF THE ACUTE ABDOMEN (THE). By Zachary Cope, M.D. Ed. 6, London, Oxford Univ. Press, Humphrey Milford, 1932.

ERDMANN'S CLINICS. By John F. Erdmann, M.D. Phila., W. B. Saunders, 1932.

FRANKFÜRTER ZEITSCHRIFT FÜR PATHOLOGIE, Vols. I and II. Ed. by Bernhard Fischer-Wasels. Munich, Bergmann, 1932.

HANDBOOK OF EXPERIMENTAL PATHOLOGY (A). By George Wagoner, M.D., and R. Philip Custer, M.D. Springfield, Ill., Chas. C. Thomas, 1932.

INJURIES OF THE EYE. By Harry Vanderbilt Würdemann, M.D. Ed. 2, St. Louis, C. V. Mosby, 1932.

KREBSVERBREITUNG, KREBSBEKÄMPFUNG, KREBSVERHÜTUNG. By Erwin Liek. Munich, J. F. Lehmanns, 1932.

LEHRBUCH DER UROLOGIE. By Leopold Casper, Berlin, Urban and Schwarzenberg, 1932.

LET'S OPERATE. By Roy H. McKay and Norman Beasley. N. Y., Ray Long and Richard R. Smith, 1932.

MANAGEMENT OF ABDOMINAL OPERATIONS (THE). By Rodney H. Maingat, M.D. N. Y., Wm. Wood, 1932.

OXFORD MEDICAL ADVISER FOR THE HOME. By John D. Comrie. N. Y., Oxford Univ. Press, 1932.

PRACTICAL OBSTETRICS FOR STUDENTS AND PRACTITIONERS. By P. Brooke Bland, M.D. Phila., F. A. Davis, 1932.

ROUNDABOUT HARLEY STREET. By Cyril Phillips Bryan, M.D. London, John Bale Sons and Danielsson, 1932.

SYLLABUS OF LECTURES ON GYNECOLOGY FOR NURSES (A). By a Committee appointed by the American Gynecological Society. N. Y., 1932.

PERIPHERAL NERVE INJURIES

LEWIS J. POLLOCK, M.D., AND LOYAL DAVIS, M.D

TWELFTH (Concluding) INSTALLMENT

CONTENTS

[This Number]

Chapter		Vol. XVIII Page
XXXV.	The Cranial Nerves (Continued)	554
XXXVI.	Extracranial Injuries of Multiple Cranial Nerves	568
XXXVIII.	The Results of Peripheral Nerve Surgery	579

[Previously Issued]

		Vol. XV
I.	The Incidence of Peripheral Nerve Injuries	179
II.	Examination: History; General Examination	183
III.	Examination (*Cont.*): Motion	185
IV.	Examination (*Cont.*): Subjective Sensory Disturbances	390
V.	Examination (*Cont.*): Causalgia	395
VI.	Examination (*Cont.*): Objective Sensory Disturbances	403
VII.	Examination (*Cont.*): Nerve Overlap	411
VIII.	Vasomotor, Trophic and Secretory Disturbances	573
IX.	Examination (*Cont.*): Electrical Examination	581
X.	Examination (*Cont.*): Reflexes	589
XI.	Diagnosis: Differential Diagnosis	592
XII.	Diagnosis (*Cont.*): Signs of Severe Nerve Injury	599
XIII.	Diagnosis (*Cont.*): Recovery of Function	605
XIV.	Development and Structure	620
		Vol. XVI
XV.	Pathology of Peripheral Nerve Lesions	141
XVI.	Histopathology of Nerve Degeneration and Regeneration	156
XVII.	Indications for Surgical Treatment	173
XVIII.	Methods of Nerve Repair	181
XIX.	Surgical Technique of Nerve Operations	353
XX.	Postoperative Treatment	377
XXI.	Treatment of Irreparable Nerve Injuries	550
XXII.	The Radial Nerve	566
		Vol. XVII
XXIII.	The Median Nerve	139
XXIV.	The Ulnar Nerve	301
XXV.	Combined Median and Ulnar Nerve Lesions	333
XXVI.	The Axillary Nerve	462
XXVII.	The Musculocutaneous Nerve	472
XXVIII.	Shoulder Girdle Nerves	480
XXIX.	The Brachial Plexus	484
		Vol. XVIII
XXIX.	The Brachial Plexus (*Continued*)	152
XXX.	The Sciatic Nerve	176
XXXI.	The Peroneal Nerve	194
XXXII.	The Tibial Nerve	362
XXXIII.	The Lumbosacral Plexus	374
XXXIV.	The Femoral Nerve	387
XXXV.	The Cranial Nerves	396

Chapter XXXV

THE CRANIAL NERVES (*Continued*)

THE FACIAL NERVE (*Continued*)

The *posterior auricular* branch arises near the stylomastoid foramen. This nerve passes upward in front of the mastoid process where it is joined by a twig from the auricular branch of the vagus. It also communicates with the great auricular and small occipital nerves. As the nerve ascends between the meatus and the mastoid process it divides into two branches. The auricular branch supplies the small muscles on the cranial surface of the pinna and retrahens auriculam. The larger occipital branch passes backward along the superior curved line of the occipital bone and supplies the occipitofrontalis muscle.

The *digastric* branch has a common origin with the *stylohyoid* branch. The former supplies the posterior belly of the digastric muscle. The latter is long and slender. It passes inward to supply the stylohyoid muscle.

The *temporofacial* is the larger of the two terminal branches of the facial. It passes upward and forward through the parotid gland. It crosses the external carotid artery and passes over the neck of the condyle of the mandible. It divides into many branches which may be divided into temporal, malar and infraorbital groups. The temporal branches cross the zygoma and supply the small auricular muscles as well as the occipitofrontalis, the orbicularis palpebrarum and the corrugator supercilii muscles. The malar branches cross the malar bone and also supply the orbicularis palpebrarum. The infraorbital branches pass forward to be distributed between the lower margin of the orbit and the mouth. Some of the branches supply the superficial muscles of the face and the pyramidalis nasi muscle. Other deeper branches supply the zygomaticus, the levator labii superioris and the levator anguli oris muscles.

The *cervicofacial* division passes obliquely downward and forward through the parotid gland where it crosses the external carotid artery. Opposite the angle of the mandible it divides

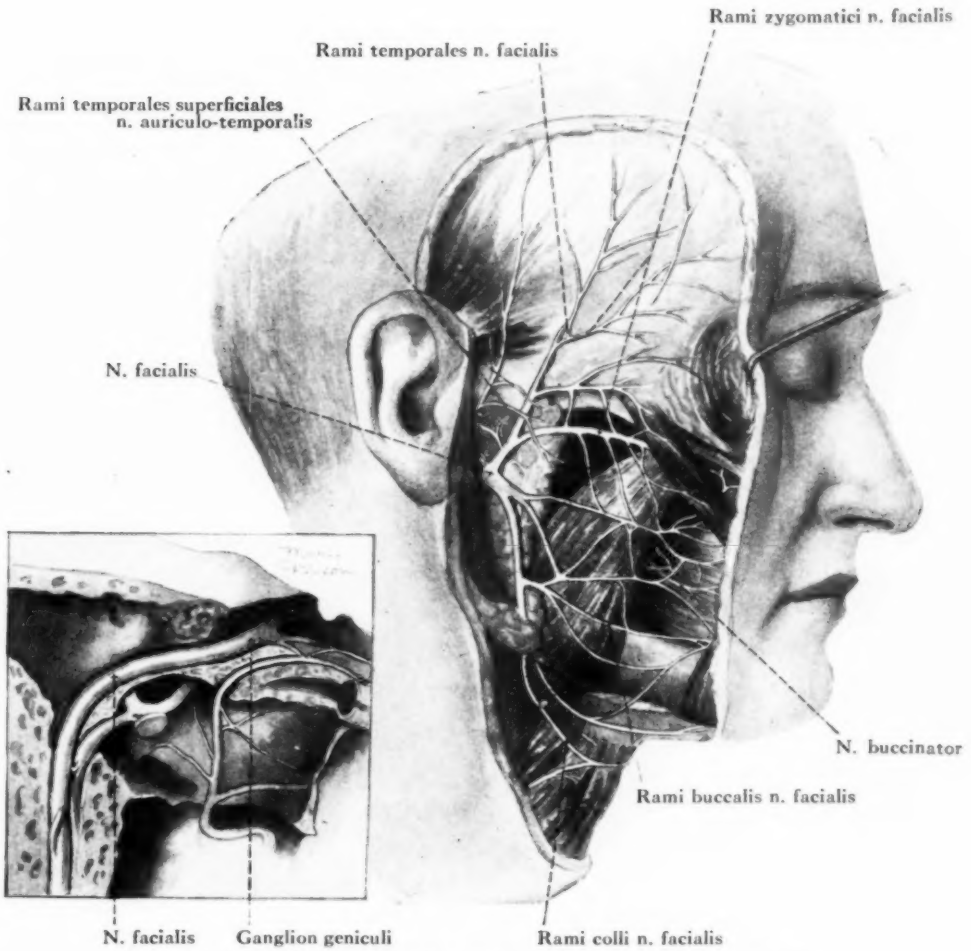


FIG. 303. Drawing to illustrate anatomical course of facial nerve.

into buccal, mandibular and cervical sets of branches. The buccal branches cross the masseter muscle and supply the buccinator and orbicularis oris muscles. The mandibular branches pass forward beneath the platysma and depressor anguli oris to supply the muscles of the lower lip and chin. The cervical branches run forward beneath the platysma

which they supply. One of these branches descends vertically to join the transverse cervical nerve.

Physiology of the Facial Nerve

As has been stated the facial is a mixed nerve. However, its major portion is motor in function. The muscles supplied by the facial are for the most part muscles of expression.

The *occipitofrontalis* muscle raises the eyebrows and the skin over the base of the nose. It also draws the scalp forward and throws the skin of the forehead into transverse wrinkles. The occipital portion of the muscle draws the scalp backward.

The *orbicularis palpebrarum* muscle is the sphincter muscle of the eyelids. The palpebral portion acts involuntarily while the orbicular portion is a voluntary muscle. When the entire muscle acts as a whole the skin of the forehead, temple and cheek is drawn inward to the inner angle of the orbit and the eyelids are closed firmly.

The *corrugator supercilii* draws the eyebrow downward and inward. The *pyramidalis nasi* draws the inner angle of the eyebrow downward.

The *levator labii superioris* muscle elevates the upper lip and carries it forward. The *levator anguli oris* raises the angle of the mouth. The *zygomaticus major* draws the angle of the mouth backward and upward while the *zygomaticus minor* draws it backward, upward and outward.

The *levator labii inferioris* raises the lower lip and protrudes it forward. At the same time it wrinkles the skin of the chin. The *depressor labii inferioris* draws the lower lip directly downward and slightly outward. The *depressor anguli oris* depresses the angle of the mouth.

The *orbicularis oris* closes the lips. It may also bring the lips in close apposition to the alveolar arch. The superficial portion of the muscle brings the lips together and protrudes them. The *buccinator* muscles contract and compress the cheeks. This action keeps the food under the pressure of the teeth during mastication. When the cheeks have been

distended with air these muscles expel it from between the lips. The *risorius* muscle retracts the angles of the mouth.

The posterior belly of the *digastric* and the *stylohyoid* muscles are important factors in the act of deglutition. After a morsel of food has passed through the pharynx the hyoid bone is carried upward and backward by these muscles. They are therefore of assistance in preventing the return of the food into the mouth.

The *sensory portion* of the facial nerve is represented by the nervus intermedius and the chorda tympani is thought to be a direct continuation of its fibers. It has been shown rather conclusively that the sensory component of the facial nerve supplies deep sensation to the face. After section of the trigeminal nerve deep pain pressure may be appreciated. In combined lesions of the fifth and seventh nerves all types of sensation are lost. Cushing and others have shown that the sensation of taste upon the anterior two-thirds of the tongue is undoubtedly carried by way of the chorda tympani and the facial nerve.

Surgery of the Facial Nerve

The facial nerve is the cranial nerve most frequently involved by trauma or disease and the one for which surgical repair is most often indicated. The nerve may be severed by a stab or gunshot wound or it may be injured inadvertently during a mastoid operation. Under such circumstances the indications for repair are quite plain. The nerve may also be torn within the cranial cavity by a fracture of the base of the skull. Cases have been recorded in which fragments of bone have compressed the nerve within the facial canal and in which simple nerve liberation have been followed by recovery. Facial paralysis may accompany an otitis media. In such cases one should wait for at least six months for spontaneous regeneration to occur. It may also follow some time after a mastoid operation in which event it may be assumed that compression and not anatomical severance has produced the paralysis.

In Bell's palsy a number of fibers to the face may function sufficiently to maintain some degree of muscle tone without a complete return of function. The nerve may be injured during childbirth by the application of forceps. Congenital maldevelopment of the facial nerve muscles may also be met but is commonly accompanied by other cranial nerve lesions.

As elsewhere in peripheral nerve surgery the ideal form of treatment is an end-to-end suture of the injured facial nerve. Because of its course within the facial canal which it fills completely this procedure is not so easy to accomplish even when the nerve has been severed by the lesion. It is therefore even more imperative that every opportunity be given for spontaneous regeneration to occur.

Occasionally the cut nerve ends may be directly sutured in an early case of division but when scar tissue and callus have developed within the facial canal this is practically impossible. Consequently other methods of nerve repair must be employed. Rarely a single autogenous graft may be used by employing a cutaneous nerve but even here the diameter of the facial canal is such that a very small amount of scar tissue may defeat an otherwise successful repair.

Frequent attempts have been made to correct a facial paralysis by the anastomosis of the distal end of the facial nerve beyond the stylomastoid foramen with the central end of another cranial nerve. The spinal accessory and the hypoglossal nerves have been most frequently used in such operations. Faure and Furet, in 1898, first performed the operation of anastomosing the spinal accessory and the facial and Körte, in 1901, first used the hypoglossal nerve in such a nerve crossing.

Many experimental investigations have been carried out to study the results of such anastomoses and many clinical cases have been reported upon. In 1900, Mannasse obtained a response in the facial musculature in three out of five dogs upon which he anastomosed the facial and spinal accessory nerves. In 1911 and later, Kennedy has reported upon similar

experimental and clinical studies. He has shown that approximately equal results may be obtained with either the hypoglossal or spinal accessory nerves. Increase of muscle tone first appeared with a definite improvement in the symmetry of the face. Return of motor function to the orbicularis oculi followed later. The eye on the affected side first closed separately but later it became associated with closure of the normal eye. He also showed that in the monkey after spinofacial anastomosis there were movements of the facial muscles associated with movements of the shoulder.

In Cushing's case of spinofacial suture there were marked movements of the facial muscles associated with turning the head or raising the shoulder. Kennedy, Grant, Hunt and others have reported marked improvement with a very small amount of associated movements. Stookey reports a case observed ten years after operation in which the only improvement was in the tone of the muscles. No emotional expression was possible. Körte stated that in his cases of hypoglossal-facial crossing voluntary movement had returned so that the orbicularis oculi contracted and the angle of the mouth could be raised.

Taylor and Clark have implanted the facial into a slit made in the hypoglossal nerve. They reported a variable return of movement in the facial musculature in all of their cases. Ballance, and Ballance and Stewart stated that the hypoglossal-facial suture was preferable to spinal accessory-facial crossing because of the fact that the cortical centers for the face and tongue are closer together. The shoulder and facial muscle movements are not synergistic and have little or no association. Frazier and Spiller also favor such an operation for the same reason. Ballance has reported a case in which the end of the facial was sutured to the hypoglossal while the end of the hypoglossal was sutured to the spinal accessory. Twenty months later this patient had a functional return in the facial muscles without associated movements of the tongue. Ballance has reported the experimental results of many investigations

in which the lingual and the descendens hypoglossi nerves have been used in such a type of operation.

The questions naturally arose during the discussion of such operations of whether or not the cortical motor center for the shoulder or tongue assumed the function of the cortical face center. Kennedy's experimental work upon nerve crossing in the extremities seemed to prove that such is the case. He found, for example, after crossing the nerve supply to the flexor and extensor muscles of the dog that stimulation of the cortical flexor center produced a response in the extensor muscles and vice versa.

Another problem always is presented in the consideration of this operation of nerve crossing. This concerns the paralysis which results from the section of the substituted nerve. Use of the hypoglossal nerve results in an atrophy of the corresponding half of the tongue. Section of the spinal accessory is of course followed by impairment of function of the arm and shoulder. The choice between these two conditions depends a great deal upon the occupation of the patient. However, as has been mentioned, attempts have been made to suture the central end of the descendens hypoglossi to the distal end of the substituted nerve with a considerable degree of success. Some feel that all things considered paralysis of half of the tongue or of the shoulder is preferable to a facial paralysis.

This has proved to be the case in a patient upon whom we operated five years ago. The patient had a complete facial paralysis on the left side which was due to a walnut-sized tumor mass between the mastoid process and the angle of the jaw. This had been present for a considerable time but her face had been paralyzed for two years. At operation the mass was circumscribed but completely surrounded the facial nerve. The mass extended into the facial canal and to remove it completely it was necessary to section the nerve high in the canal. However, a long distal segment of the facial was isolated. This was sutured to the central end of the spinal accessory. The photographs illustrate the facial appearance before, six

months, and one year after operation (Fig. 304). The return of tone in the facial muscles has been rapid so that the symmetry of her face is more nearly normal. One year after opera-

FIG. 304. Result of spinofacial anastomosis performed five years ago. A: Before operation; B: Nine months after operation; C: Four years after operation; D: Five years after operation.

tion she was unable to close her eyelid although she had good voluntary movements about her mouth. These were unasso-

ciated with movements of the shoulder. The disability produced by the impairment of function of her shoulder has not been sufficient to detract from the clinical result obtained.

Sherren collected 50 cases of facial nerve suture. A great many of the operations which had been performed were implantations or partial nerve crossings. In 8 cases the anastomosis was complete but only 2 were followed longer than six months after operation. One of these was a spinofacial and the other was a hypoglossofacial crossing. In both associated movements were present. In most of the operations, however, definite improvement in the symmetry of the face had resulted.

Schmidt anastomosed the facial and hypoglossal nerves in a patient who had been wounded by a gunshot projectile. Two and a half years after the operation the patient could draw the eyebrow inward and downward but could not contract the frontalis muscle. He could close his eye almost completely and the corner of the mouth could be drawn outward and upward.

Technique of Spinofacial Anastomosis: The facial nerve should be exposed first. The incision should extend downward and forward from above the tip of the mastoid process. The posterior occipital vein usually crosses the line of incision and must be ligated. In making the incision through the deep fascia care should be taken not to open the parotid gland sheath. The gland should be freed carefully and held forward by a blunt retractor. The nerve may be identified usually by palpation at its exit from the stylomastoid foramen. If, however, there is a large amount of scar tissue present it may be necessary to remove the tip of the mastoid with the sternocleidomastoid muscle attachments. The digastric muscle may also make it difficult to find the nerve. While its retraction downward and backward is usually all that is necessary it may be a help to cut a part of its fibers transversely to aid in the exposure. The facial trunk should be isolated as high as possible in the canal. Sutures should be placed through the sheath just distal to the point at which it is to be sectioned.

Book Page 532

Through the same incision the spinal accessory nerve is sought. It lies posteriorly and crosses the transverse process of the atlas before it turns downward to cross the medial surface of the sternomastoid at the junction of its middle and upper thirds. A deep layer of fascia which encloses the transverse process of the atlas and the internal jugular vein should be opened to expose the nerve. The occipital artery runs along the lower border of the digastric muscle and should be isolated and ligated.

The spinal accessory is dissected free and the point of division decided upon. Here again sutures are passed before the nerve is sectioned so as to avoid any unnecessary trauma to the nerve trunk. The end-to-end suture is then performed between the distal end of the facial and the central end of the spinal accessory in the same manner as is used in any other direct nerve suture.

Exposure of the Hypoglossal Nerve: The same incision as has been described may be used to perform a hypoglossal-facial anastomosis. However, the lower end of the incision should be carried slightly more forward. The digastric muscle is retracted upward and the sternomastoid downward and posteriorly. The carotid sheath should be opened and the hypoglossal may then be identified as it curves forward with its convexity downward to cross the internal and external carotid arteries. If there is any question about the identification the nerve may be stimulated by an electrode. The vagus, of course, has a direct course downward and lies posterior. After the nerve has been freed sufficiently sutures are placed through the sheath and it is sectioned at the point of election.

Exposure of the Descendens Hypoglossi: It is highly desirable to complete these operations by anastomosis of the distal end of either the spinal accessory or hypoglossal nerves to the central end of the descendens hypoglossi. Regeneration through such a suture line prevents sacrifice of function which follows section of the hypoglossal and spinal accessory nerve trunks.

The descendens hypoglossi runs along the lateral border of the hypoglossal nerve as it courses downward. It should be sectioned as low as possible so that its central end may be utilized for the suture without tension.

The lines of suture should be placed between or upon normal muscle tissue and protected in that manner. If the sutures are accomplished under tension a light immobilizing collar bandage of crinoline may be necessary until the line of suture is healed.

POSTOPERATIVE TREATMENT: The facial muscles should be kept from sagging and overstretching just as are the paralyzed muscles of an extremity. A simple mechanical device which will lift the angle of the mouth and the muscles of the cheek consists of an adhesive tape bridge. One end may be attached to the skin in the anterior temporal region and the other to the skin near the angle of the mouth.

We have also found Stookey's suggestion a valuable one. A small band may be worn about the head or a spring steel metal over the head like that worn by telephone operators. A strap of adhesive is attached to the skin of the face. In the free end of the adhesive a small metal hook is placed which is attached to the head band by a rubber band. This may be adjusted so that it forms an elastic rather than a fixed support. Some such a device should be worn constantly by the patient.

At the same time the patient should receive daily massage and gentle galvanic or sinusoidal stimulations to the facial muscles. Educative exercises should be taught to the patient and these should be performed before a mirror, particularly after the appearance of the first return of function.

PLASTIC OPERATIONS: The aim of plastic operations in facial paralysis is to relieve the disfiguring asymmetry of the face by elevation of the lower eyelid or the angle of the mouth. Lexer suggested the use of a pedunculated flap from the anterior border of the temporal muscle to be sutured along the lower lid to the orbicularis palpebrarum. Momburg used an aluminum bronze wire which he attached to the periosteum

of the zygoma and passed to the angle of the mouth. Kirschner, Busch, Stein and Fischer have all described and used a free transplant of fascia lata for the same purpose. Through a

FIG. 305. Drawing of operative technique for plastic operation to relieve facial paralysis. (After Blair.)

small incision in the skin over the zygoma, the fascia lata is looped around this bone. One end of the fascial strip upon a straight long needle is pushed subcutaneously toward the angle of the mouth until it reaches a point on the upper lip 1 cm. above the commissure of the lips. The needle is pushed through the mucous membrane and the fascial strip pulled through. A small incision is made vertically downward through the mucous membrane to a point 1 cm. below the commissure. The needle is then pushed through the musculature of the cheek and is carried upward subcutaneously to the zygoma. The two ends of the fascia are pulled taut and the angle of the mouth raised as high as desired. They are then tied securely. Blair makes use of several fascia lata transplants which are anchored in the temporal fascia and are attached at the angle of the mouth, the nasolabial fold and the upper and lower lips (Fig. 305). Gersuny has joined the fibers of the paralyzed half of the orbicularis oris to those of the sound side

by making small incisions through the mucous membrane of the upper and lower lips. Failures of these operations may be traced to an insufficient amount of correction and to the fact that the grafts may shrink. All strain should be taken from the newly implanted fascia by external support of the facial tissues. Blair suggests that the mechanical fixation of facial muscles may be used in connection with a nerve crossing operation. It would limit the overstretching of paralyzed muscles and would lessen the load during the return of muscle function after such a nerve operation.

Spinal Accessory Nerve

When injured alone, the external branch which innervates the trapezius and the sternocleidomastoid muscles is involved. The internal branch, which joins the vagus soon after its exit from the cranium, supplies the muscles of the larynx and those of the soft palate. When the external branch of this nerve is paralyzed there ensues a paralysis of the sternocleidomastoid and the trapezius muscles. On turning the head to the opposite side the paralyzed sternocleidomastoid muscle does not contract and the head may be only incompletely turned to the side. In addition to the spinal accessory the trapezius muscle receives innervation from the cervical nerves so that frequently a complete section of the spinal accessory is followed by only a partial paralysis of the trapezius. The middle and infraspinous portion of the muscle is frequently spared, but when the cervical nerves are injured as well the disability is much greater. The trapezius muscle elevates the shoulder and adducts the shoulder blade toward the midline. When contracting unilaterally, the shoulder of the corresponding side is elevated, the head is drawn backward and rotated somewhat to the opposite side. When the clavicular portion of the muscle is paralyzed the shoulders do not move in respiration. When the middle portion is paralyzed the acromion falls, as the result of the weight of the arm. The upper and inner angle of the scapula is raised and displaced outward by the

levator anguli scapuli, while the inner and lower angle is approximated to the midline. The shoulder is drawn forward and downward and cannot be adducted in the usual manner.

FIG. 306. Paralysis of the spinal accessory nerve.

In paralysis of the lower portion, the internal margin of the scapula is displaced outward, thus broadening the back, and the acromial portion of the clavicle is projected forward (Fig. 306).

Frequently the arm may be abducted quite adequately, but if all parts of the trapezius are paralyzed attempts to abduct the arm are followed by a forward and upward dislocation of the shoulder blade. The patient is unable to abduct the shoulder in the first third of the movement unless the shoulder blade is passively held against the chest wall.

Chapter XXXVI

EXTRACRANIAL INJURIES OF MULTIPLE CRANIAL NERVES

Simultaneous lesions of the ninth, tenth and eleventh cranial nerves have frequently been observed as the result of war injuries. Often an injury of one or more additional nerves has been present. Most frequently the twelfth, occasionally the cervical sympathetic and rarely the seventh nerve have been involved.

Extracranial lesions of the last four cranial nerves had rarely been observed prior to the war. Such cases were attributed either to compression by a tumor, gumma or tuberculous gland, or to an inflammatory condition. One of the most striking examples of such a case was reported by Beck and Hassin.

Lesions of the ninth, tenth and eleventh cranial nerves were more frequently noted as the result of non-traumatic causes about the jugular foramen. Vernet has described 6 such cases due to compression, 2 of which were observed by him. Three others were the result of inflammation and 2 of these were his own cases.

The cases which present lesions of several or all of the last four cranial nerves have been classified on the basis of symptoms added to a pure laryngeal hemiplegia. Thus, the syndrome of Avellis consists of a unilateral paralysis of the soft palate, in addition to the larynx, as the result of a lesion of the vagus and the internal branch of the spinal accessory nerves. The syndrome of Schmidt is characterized, in addition to the foregoing symptoms, by paralysis of the sternocleidomastoid and the trapezius muscles through the inclusion in the lesion of the external branch of the spinal accessory nerve. The syndrome of Jackson includes, in addition to all of these symptoms, unilateral paralysis of the tongue resulting from a lesion of the hypoglossal nerve.

Several new groups have been added by the literature of the war. Vernet has described a syndrome due to a combined lesion of the glossopharyngeal, vagus and spinal accessory

FIG. 307. Photograph of model to show extracranial course of last four cranial nerves: (—) spinal portion of spinal accessory; (=) hypoglossal; (≡) vagus; (≡) glossopharyngeal.

nerves, called by him the syndrome of the posterior lacerated foramen. Collet described a combination of symptoms due to a complete lesion of the ninth, tenth, eleventh and twelfth cranial nerves under the name of glosso-laryngo-scapulo-pharyngeal hemiplegia. The same condition was described by Vernet as the complete syndrome of the last four cranial nerves and by Sicard as the syndrome of the condyloposterior lacerated foramen. Villaret described the syndrome of the posterior retroparotid space, which is characterized by the addition of a lesion of the sympathetic nerve to the syndrome of the last four cranial nerves, producing thereby enophthalmos, narrowing of the palpebral fissure and myosis. The number of syndromes is limited only by the possible combinations

of complete or incomplete paralyses of these several cranial nerves, and the descriptive ability of the various observers.

One of the notable features of all the cases is that whatever

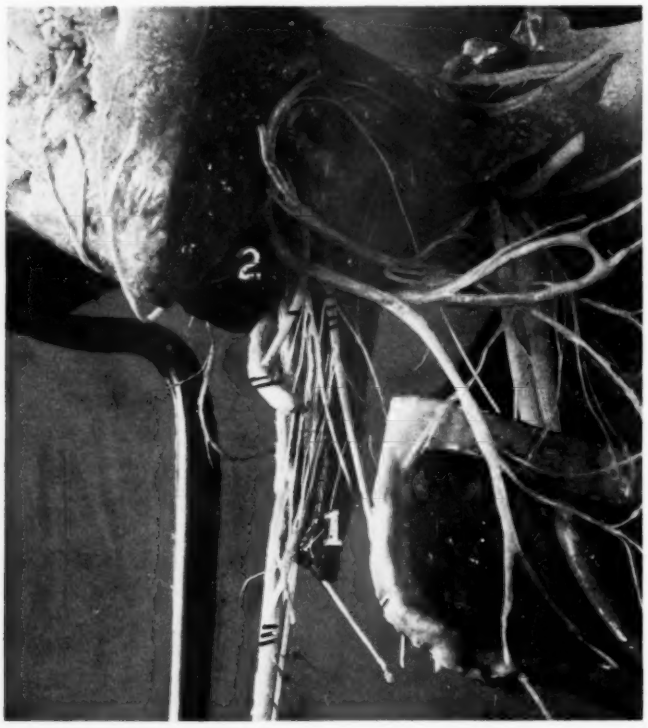


FIG. 308. Photograph of model to show extracranial course of last four cranial nerves: (—) spinal portion of accessory; (=) hypoglossal; (≡) vagus; (≡) glossopharyngeal.

other nerves might be affected the ninth, tenth and eleventh are rather consistently injured together. Such lesions are produced by wounds in the uppermost part of the lateropharyngeal space. This space is bounded above by the base of the skull in the region of the jugular foramen. The jugular foramen, or posterior lacerated foramen, is an opening of irregular shape and size, placed between the petrous portion of the temporal bone in front and the jugular process of the occipital bone behind. The foramen is occasionally divided into two parts by the spicules of bone which bridge it. It presents three compart-

ments. Through the anterior compartment passes the inferior petrosal sinus; through the posterior the internal jugular vein and some meningeal branches from the occipital and ascending

FIG. 309. The relation of the hypoglossal (12) and sympathetic (S) to the vagus (10).

pharyngeal arteries; and between the two veins, in order from before backward, are the glossopharyngeal, vagus and spinal accessory nerves (Figs. 307, 308, 309).

At its exit from the jugular foramen the jugular vein lies to the outside of the nerves; closely in front and internally lie

the internal carotid artery and the accompanying sympathetic nerves. At this point, Vernet states, it is possible for a projectile passing obliquely from the mastoid region on one side to the malar bone on the other to injure the three nerves and miss both the carotid and jugular vessels. This was usually the direction of the course of the missile in the cases under observation. In many cases, however, such a route was not followed. The fact that such patients survived the injury, which produced a paralysis of the three cranial nerves, without a contralateral hemiplegia, indicates one of two conditions: either severe injuries to the carotid and jugular vessels need not be fatal or result in a contralateral hemiplegia, or these cranial nerves may sustain traumatic lesions without injury of the carotid and jugular vessels. Contusion, concussion, pressure by hematomas and arterial and arteriovenous aneurysms may likewise produce loss of function of cranial nerves.

In certain respects, injury of the last four cranial nerves resembles injury of the brachial plexus. A complete brachial palsy which immediately follows injury of the plexus may improve gradually until only one or more of the cords are permanently paralyzed. In a like manner complete paralysis of the last four cranial nerves frequently eventuates in a permanent paralysis of only one, with partial lesion of one or more of the others.

In their peripheral course, the last four cranial nerves are in close proximity to a point a short distance below the level of the tip of the mastoid. Thus lesions of the ninth, tenth and eleventh cranial nerves have been produced at times by an injury not directly involving the posterior lacerated foramen.

Whether or not cranial nerves other than the ninth, tenth and eleventh are injured depends on the direction and the level of the course of the projectile. The frequent inclusion of the hypoglossal nerve in these injuries is easily understood when we recall the proximity of its exit through the anterior condyloid foramen to the jugular foramen. Likewise it is in close proximity to the ninth, tenth and eleventh cranial nerves

in the retroparotid space where its injury is frequently associated with a lesion of the sympathetic nerve. This space is described by Villaret as being bounded posteriorly by the cervical spine, internally by the pharynx, anteriorly by the internal prolongation of the parotid gland and the muscular bundle attached to the styloid process and above by the base of the skull in the region of the jugular foramen.

The symptomatology of a combined lesion of the ninth, tenth and eleventh cranial nerves is constant and easily recognized. As a characteristic triad of symptoms indicative of a complete lesion of these three nerves, Vernet proposes nasal regurgitation of fluids, dysphagia of solids and hoarseness. These symptoms represent respectively paralysis of the palate, pharynx and larynx. Which part of the collective symptomatology may be attributed to any one of these nerves is more difficult to interpret.

Considerable confusion exists concerning the innervation of the soft palate and larynx. The specific functions of the accessory portion of the spinal accessory and the vagus nerves are undetermined. Whether or not it would be more profitable to consider their functions together as those of the vagospinal nerves remains to be seen. The glossopharyngeal nerve, according to Vernet, innervates the superior constrictor of the pharynx. Loss of its function results in difficulty in swallowing solids. In lesions of this nerve, the posterior wall of the pharynx deviates to the unaffected side when the patient says "ah" with the tongue pulled forward, and there is disturbance of taste on the posterior third of the tongue. A lesion of the vagus nerve produces sensory loss on the soft palate and the posterior wall of the pharynx in addition to the well-recognized disturbances of salivation and of respiration (dyspnea or pseudo-asthma). Injury of the accessory portion of the spinal accessory nerve causes paralysis of the soft palate and larynx as well as a rapid pulse; while a lesion of the spinal portion produces paralysis of the sternocleidomastoid and trapezius muscles.

These cases are of such interest that a short description will be given of some of them.

CASE 1. S. R., was wounded August 10, 1918, by a machine-gun bullet. The wound of entrance was 1½ inches to the left of the fourth cervical spine, and the wound of exit ½ inch below the anterior extremity of the left zygomatic arch. He was unconscious for half an hour. When attended by a medical officer one and one-half hours following the injury, he was hoarse, dyspneic, had difficulty in swallowing and there was marked salivation.

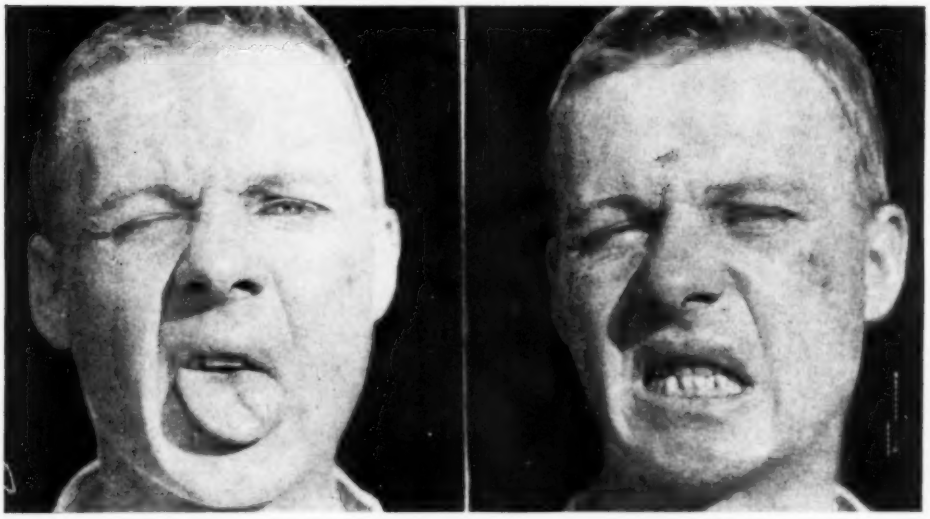
The patient was examined ten days after injury. There was a subconjunctival hemorrhage of the left eye. A hemorrhage into the mucous membrane of the posterior wall of the pharynx extended well up into the mouth of the esophagus. A peripheral paresis of the left seventh nerve and paralysis of the ninth nerve were present. He had considerable difficulty in swallowing solid food. The posterior wall of the pharynx was pulled toward the right, especially when the tongue was pulled forward. No disturbance of taste could be demonstrated.

There was paralysis of the vagospinal nerves; that is, of the accessory portion of the spinal accessory and the vagus. He had moderate salivation and sensation over the left side of the soft palate was diminished. No disturbance of respiration was noted. There was paralysis of the left side of the soft palate. The latter was pulled to the right and in phonation this deviation was increased. There was some regurgitation of fluids. The gag reflex was absent on the left. The left vocal cord was paralyzed and the voice was hoarse and nasal.

There was paralysis of the sternocleidomastoid and the trapezius muscles. On turning the head to the right only a small portion of the sternal part of the sternocleidomastoid became prominent. The shoulder drooped. The inner angle of the scapula deviated outward, the outer angle drooped and the lower angle approximated the midline and projected under the skin. The left hypoglossal nerve was paralyzed. The tongue, while in the buccal cavity, was pulled slightly toward the right. When it was protruded, it deviated to the left and showed atrophy and fibrillary twitching.

Comment: In this case we were dealing with an extracranial injury of the ninth, tenth, eleventh and twelfth cranial nerves and a partial lesion of the seventh. The course of the missile did not conform to the usual diagonal route from the mastoid region of one side to the malar of the other (Fig. 310).

CASE II. H. P., was wounded April 5, 1918, by a pistol bullet. The wound of entrance was just above the upper central incisors and the wound of exit one inch below and 2 inches behind the right mastoid process. For



A B

FIG. 310. A: Weakness of left facial and hypoglossal palsy; B: Weakness of left facial and paralysis of sternocleidomastoid.

several days following the injury he was unable to move his left arm and leg. He had difficulty in speaking, hoarseness and slight regurgitation of liquids. He preferred semisolid food, as solid food was hard to swallow.

He was examined over a year after the injury. The deep reflexes on the left side were all greater than on the right; the plantars were equal and normal; the cremasterics equal; and the left upper abdominal reflex was diminished. There were no sensory disturbances over the extremities, trunk or abdomen, and no weakness in these regions was noted. It is probable that he sustained a unilateral concussion of the spinal cord at the time of injury.

A lesion of the cervical sympathetic of the left side was shown by enophthalmos, diminution in the size of the palpebral fissure and a contracted pupil. Indicating a lesion of the ninth nerve was a history of dysphagia for solids and slight deviation of the posterior wall of the pharynx to the left on protruding the tongue. Taste was not affected.

There was a history of regurgitation of fluids and hoarseness but no history of disturbance of respiration, pulse and salivation. No objective findings were present.

In the distribution of the spinal portion of the spinal accessory there was found slight atrophy of the trapezius muscle but none of the sterno-cleidomastoid.

A B C

FIG. 311. A: Facial weakness and narrowed palpebral fissure, enophthalmos and myosis. B: Atrophy of tongue. C: Anterior dislocation of shoulder girdle on attempts to shrug shoulders.

The twelfth nerve was paralyzed. The right half of the tongue, with the exception of the inner part of the very tip, was markedly atrophied. Slight paresis of the facial muscles of the right side was seen.

Comment: In this case we were dealing with a permanent paralysis of the twelfth nerve and the cervical sympathetic, and with a dissociated and recovering lesion of the ninth, tenth and eleventh cranial nerves. In addition, a slight lesion of the seventh nerve was present. This case is illustrative of the retroparotid syndrome of Villaret. Many such cases have been noted and described among others by Villaret; Faure; Lannois, Sargnon and Vernet; and Sicard and Roger (Fig. 311).

CASE III. C. L. was wounded October 10, 1918, by a high explosive shell. The wound of entrance was at the tip of the left mastoid. The missile was located by roentgenogram in front of the axis in the midline. Following the injury he was unconscious for six hours.

He was examined ten days after injury. He showed no paralysis of the extremities, trunk or abdomen. There were no sensory disturbances. No dysmetria, adiadochocinesia or other dyssynergia was found.

The findings may be divided into two groups: first, paralysis of the left facial and auditory nerves; second, paralysis of the ninth, tenth, eleventh and twelfth cranial nerves of the same side. There was a complete peripheral

A B

FIG. 312. A: Deviation to opposite side with tongue in the mouth. B: Deviation to the side of the lesion when the tongue is protruded.

facial palsy of the left side, loss of taste on the entire left side of the tongue and total deafness on the same side. He gave a history of tinnitus and in his record was a notation of gradually diminishing horizontal and lateral nystagmus to the right. Such a nystagmus of mild degree was found. There was escape of what appeared to be cerebrospinal fluid from the left ear. Because of this, caloric tests were not performed, and turning tests were omitted because of the general condition of the patient. Roentgenograms did not reveal a basilar skull fracture.

Because the peripheral facial palsy was associated with loss of taste on the anterior two-thirds of the tongue, and there was injury to both the cochlear and vestibular portions of the eighth nerve, it was concluded that the injury occurred in the peripheral part of the seventh and eighth nerves within the petrous portion of the temporal bone.

Dyspnea, hoarseness, nasal speech, palatal palsy and anesthesia and paralysis of the left vocal cord indicated paralysis of the vagospinal nerves. A complete or severe lesion of the ninth nerve was shown by paralysis of the superior constrictor of the pharynx and loss of taste on the posterior

third of the tongue. Involvement of the spinal portion of the eleventh nerve was shown by paralysis of the sternocleidomastoid and trapezius muscles. The left side of the tongue showed fibrillary twitching (Fig. 312).

Comment: The extracranial origin of the paralysis in Case III is not as certain as in the other two because of the involvement of the eighth nerve and the escape of cerebrospinal fluid from the ear. The absence of paralysis and sensory disturbances of the extremities and of cerebellar dysfunction speaks against a central origin. An intracranial but peripheral lesion would require an injury of wide extent, which the roentgenographic examination failed to reveal. The course of the missile was such that it traversed the upper part of the lateropharyngealspace. It does not seem possible that it could have avoided injury to at least some if not all of the last four cranial nerves.

The course of the missile in these cases conformed to no rule except to traverse the upper lateropharyngeal space. Whether the carotid artery or the jugular vein was injured could not be ascertained. In all of them the facial nerve was injured, as in the cases of Rimbaud and Vernet, Halphen and Bourcart, Lannois and Vernet. It is probable that many more cases of injury of the last four cranial nerves might have been recorded had they been observed soon after injury. Undoubtedly a number of them recovered sufficiently to leave a permanent paralysis of only one nerve. They were then misinterpreted when they were examined some time after injury.

Chapter XXXVII

THE RESULTS OF PERIPHERAL NERVE SURGERY

From the beginning of the late war neurologists and surgeons were surprised at the high incidence of wounds of the nerves. At first both neurologists and surgeons avoided operative interference because the results of the first operations were not those which had been anticipated from the neurological literature of civil practice. In France, M. and Mme. Dejerine advised resection of every cicatrix of a nerve trunk which manifested clinically the "syndrome of complete interruption." Their opinions influenced many surgeons, who began to perform resections and sutures.

The conditions under which many of the patients were operated upon, the pressure of the work and the lack of coordination between neurologist and surgeon, as well as the impossibility of re-examination over a long period of time, served to make the earlier statistics valueless. Only when the cases were separated into special groups and placed under the observation of trained men, and re-examination made possible, was there any opportunity for determining the value of operative procedures. This ideal condition was met with in but few instances, and most of the available statistics are based upon the observation of those other than the surgeons who operated upon the lesions. Not only is this the case, but often re-examinations could not be conducted over long periods of time by the same observer. Very often the patient could be re-examined no longer and recourse was had to questionnaires. That such a condition would lead to divergent opinions was to be expected, and the situation can well be visualized by the table illustrating the results in a group of cases of secondary suture which were collected by Foerster. (Table 1.)

The failures here may be seen to range from 3 per cent to 87.5 per cent. Of two men who had a large material, one had a

failure of 3 per cent in 370 cases, the other 64.3 per cent in 414 cases.

TABLE 1

RESULTS OF SECONDARY NERVE SUTURES (AFTER FOERSTER)

Author	Cases (Per Cent)	Success (Per Cent)	Improved (Per Cent)	Better (Per Cent)	Failure (Per Cent)
Foerster	370	96.0	55.0	42.0	3.0
Stracker	147	75.0	13.0	62.0	25.0
Roeper	84	22.7	6.0	16.7	77.3
Ranschburg	414	35.7	....	....	64.3
Stoffel	127	62.0	23.0	36.0	38.0
Spielmeyer	100	59.0	23.0	36.0	41.0
Borchardt	59	59.3	....	....	40.7
Perthes	74	66.0	....	....	34.0
Lehmann	69	39.1	....	....	60.9
Mauss and Kruger	42	43.0	....	....	57.0
Kunzel	44	67.7	....	....	32.3
Pelz	18	22.2	....	....	77.8
Moro	17	82.3	....	....	17.7
Hofmann	22	81.8	....	....	18.2
Herzog	16	12.5	....	....	87.5
Wexberg	57	54.5	....	....	45.6
Ranzi	31	48.4	....	....	51.6
Kakula	40	70.0	....	....	30.0
Rost	24	56.5	....	....	44.5
Cassirer	78	51.0	....	....	49.0
Steinthal	40	27.5	....	....	72.5
Total	1873	60.0			40.0

Not all of this diversity of result can be due to differences in material, facilities for good work or skill of the operators. Unless measured by similar standards such comparisons are valueless. The criteria of success differ in each instance. Foerster classed all cases as successful, which showed the recovery of a large majority of muscles so that the limb was useful regardless of whether or not sensation had returned. Under improved cases he grouped those ulnar lesions in which all but the intrinsic hand muscles had recovered, those median nerve lesions in which all muscles but the abductor pollicis brevis had regained function and those radial nerve lesions

in which all muscles but the long and short extensors of the thumb had recovered.

Many authors judged successful results by the return of function in the supinator longus in radial nerve lesions; the flexor carpi ulnaris in ulnar nerve lesions; the flexor carpi radialis in median nerve lesions; and the gastrocnemius in sciatic nerve lesions. Others speak of success judged by the ability of the patient to use the hand practically. Often a return of protopathic sensibility or shrinkage of the area of loss of pain has been used as an index of recovery. Beginning of regeneration has been used synonymously with success, and the completeness of recovery or the residuals of loss of function have often been overlooked. This is partly due to the fact that in many instances sufficient time had not elapsed following operation to permit of the evaluation of *end results.* Often when sufficient time had elapsed the patients were no longer available for examination.

In 1921, Harry Platt stated that the difficulty of keeping patients in a hospital for long periods of time was such that it explained the comparative paucity of operative statistics produced in England up to that time, and that the same deficiency was seen in the literature of the European countries. "From America," he said, "where practically every nerve injury was sustained in 1918 and the prompt segregation of all patients was affected from the beginning, and where the operations were carried out under conditions of less physical strain, valuable contributions should be forthcoming in the near future." How sadly we have failed in this respect can be seen from the total barrenness of the American literature. During 1919 the supervision of neurosurgical cases which remained under observation and which seemingly did not require operative treatment was transferred to the United States Public Health Service, under the Bureau of War Risk Insurance. In 1921, the cases were taken over by the United States Veterans Bureau. The necessity of obtaining information from three governmental sources, with different personnel,

and the discharge of most of the patients who were operated upon soon dissipated the hope of carefully following the progress of these cases.

Under the best possible conditions, reports are valuable only as they are based upon common factors in examination and the interpretation of the results of such examinations. The return of a patient to work certainly cannot be used as an index of recovery in ulnar nerve lesions, where even stenography and typing might be successfully employed. If supplementary motility is not carefully excluded many cases may be called partly successful. The early return of protopathic sensibility in certain areas, or the shrinkage of analgesia is only due to the assumption of function of adjacent uninjured nerves. Changes in the color or nutrition of the skin are valueless as indications of recovery.

The length of time following operation must be the same in comparing the results of groups of cases. In the American material sufficient time had not elapsed to permit anyone to draw any final conclusions.

TABLE II
END RESULTS OF NERVE SUTURE*

Nerve	Good	Mediocre	Negative
Brachial plexus	0	100	0
Radial	11	66	22
Median	12	56	32
Ulnar	5	72	22
Sciatic	1	60	38
Peroneal	0	50	50
Tibial	0	50	50

* Surgeon General's Report of the Medical Department of the United States Army in the World War.

In a table in the Surgeon General's Report of the Medical Department of the United States Army in the World War, the percentage of end results of 400 cases of nerve suture is given as shown in Table II.

In addition to the statistics found in the German literature mention may be made of the following. In 158 cases of suture Forrester-Brown noted 28 per cent of complete motor recovery; 19 per cent of complete sensory recovery; 21 per cent of trophic recovery; and 50 per cent incomplete in all.

Jalcowitz reported 57 cases of resection and suture of nerves. Of these there was no improvement in 28; moderate improvement in 19; extensive improvement in 2; and recovery in none. Inasmuch as these cases were examined from seven to ten years after injury they are *end results.*

Delagénière reported 142 cases in which sutures were correctly performed. Of these there was complete success in 85.91 per cent; partial success in 11.26; and failure in only 2.81 per cent.

Wiart, in 25 cases of suture, noted 20 per cent recovery; 20 per cent improved motor function; 52 per cent failures; and .8 per cent improvement in sensation or response to electrical stimulation.

Paul Dane reported 63 cases of nerve suture. In 14, a perfect result ensued; a good result in 13; a fair one in 18; and a bad result in 18. Perfect recovery meant full motor or sensory recovery; good indicated that there was considerable recovery in motor power in some muscles; fair, that there were some signs of recovery, such as diminution in the area of anesthesia or change in the tone of the muscle. Kennedy reported that 73 per cent of all sutures were completely successful.

Stopford described the results of secondary suture of peripheral nerves accurately and was able to observe his cases for a long time and make many examinations. His conclusions are among the most important available. He reported upon 271 cases. From the tables illustrating his article we have made the following analysis. Of 245 cases, there were 30 failures and 16 had shown no signs of regeneration in from six to thirteen months. A number of cases in which protopathic sensibility had begun to return were included among the successes.

Platt, in an equally accurate analysis, reported 150 cases of sutures with recoveries in 79 per cent and failure in 21.3 per cent. Sensory recovery alone was noted in 16 cases.

Our own material[1] is practically valueless from the standpoint of end results of secondary sutures. Of 81 cases, only 42 were examined at intervals more than three months after suture. Of these 27, or 64.28 per cent, showed some recovery in motion or motion and sensation; in 3 sensory regeneration, *not overlap*, had occurred alone.

Interval between Operation and Injury

It is generally accepted that the influence of the time factor has been definitely proved. Little difference is seen in the cases operated upon within eighteen months following injury, although Stracker has pointed out that the quality and type of regeneration is definitely affected.

Ranschburg had 59 cases operated upon less than six months after injury, with 47 per cent successful results; 147 cases operated upon six to twelve months, 41 per cent; one to two years, 25 per cent; more than two years, 9 per cent.

Of 21 cases operated upon within three months after injury Stracker reported success in 66 per cent; four to six months, 46 cases, 50 per cent; seven to twenty-two months, 69 cases, 24 per cent.

Stopford believed that a delay of from twelve to eighteen months appears to have no marked effect upon the date or extent of recovery. If the interval exceeds this time, the prognosis is not so good when the suture has been performed in the distal part of the limb; whereas in the proximal part a delay of two to three years does not seem to prejudice the chances of success.

Foerster's view as to the influence of time upon the beginning of recovery may be seen from the following table:

[1] Almost all of these cases were operated upon by Dr. Dean Lewis.

TABLE III

INFLUENCE OF TIME INTERVAL UPON BEGINNING OF RECOVERY (FOERSTER)

Interval between Wound and Operation Months	Number of Cases	Complete Section Recovery began Months
1	3	4.6
2	24	5.8
3	36	3.8
4	48	5.2
5	61	4.8
6	37	5.1
7	26	5.0
8	17	5.2
9	24	5.9
10	24	5.5
11	12	4.4
12	20	5.2
13	9	
14	2	
15	3	
16	3	
17	4	4.1
18	1	
19	1	
25	1	
29	2	

Jalcowitz also classified his cases with reference to the results, together with a consideration of the interval elapsing between injury and operation (Table IV).

TABLE IV

INFLUENCE OF TIME INTERVAL UPON BEGINNING OF RECOVERY (JALCOWITZ)

Interval (Months)		Improvement			Recovery
		None	Moderate	Extensive	
Less than 3	11	4	6	1	
3–6	27	7	15	5	
6–9	31	13	15	3	
9–12	15	12	3		
More than 12	12	10	2		
	96	46	41	9	

Dane tabulates the time interval as follows:

TABLE V

INFLUENCE OF TIME INTERVAL UPON BEGINNING OF RECOVERY (DANE)

Result	Interval of Time in Months between Wound and Operation
Ulnar Nerve	
Perfect	9, 1, 10, 3, 4
Good	9, 15, 5, 3, 12, 14, (1 unknown)
Fair	1, 1 day, 8, 9, 4
Bad	9, 7, 14, 7, 10, 1 day
Median Nerve	
Perfect	7, 9, 5
Good	10
Fair	1 day, 7, 3, 4, 14, 3, 8, 12
Bad	15, 5
Sciatic Nerve	
Perfect	7, 2 weeks, 4
Good	6, 12, 18
Fair	10
Bad	1 day, 7, 7, 34, 25, 12
Musculospiral Nerve	
Perfect	3, 6, 2
Good	11, 12
Fair	14, 9, 15, 7
Bad	13, 11, 10

It has seemed to many authors (Athanasio-Bénisty, Mendelssohn, Braquehage and Carriere) that primary sutures result in relatively rapid and constantly favorable results. Of 9 such cases in our series all showed complete motor recovery; 6 complete sensory recovery; and 3 partial sensory recovery, *not overlap.*

INDIVIDUAL NERVES

The statistics relative to individual nerves are exposed to the same inaccuracies noted above and, in addition, it is necessary to emphasize that in ulnar nerve lesions, supplementary motility is so extensive that many errors are possible in interpreting possible regeneration. This is equally true of combined ulnar and median nerve lesions where the strength of movement of the phalanges does not indicate which nerve

TABLE VI

RESULTS OF NERVE SUTURES UPON INDIVIDUAL NERVES (AFTER FOERSTER)

Nerve	Foerster				Stracker			Ranschburg			Spielmeyer				Stoffel			Lehmann			Borchardt			Perthes			Summary		
	No.	S %	I %	F %	No.	S %	F %	No.	S %	F %	No.	S %	I %	F %	No.	S %	F %	No.	S %	F %	No.	S %	F %	No.	S %	F %	No.	S %	F %
Radial	109	56.0	39.4	4.6	43	74.0	26.0	121	52.0	48.0	32	34.3	34.3	31.3	22	68.2	31.8	18	61.0	39.0	20	75.0	25.0	32	72.0	28.0	397	72.0	28.0
Median	83	41.0	56.6	2.4	23	83.0	17.0	47	27.5	27.5	16	25.0	25.0	50.0	4	50.0	50.0	11	36.4	63.6	3	66.6	33.4	11	73.0	27.0	198	69.0	31.0
Ulnar	64	43.9	54.9	0.8	40	57.0	43.0	72	33.0	67.0	12	25.0	8.4	66.6	5	40.0	60.0	15	26.7	33.3	9	33.4	66.6	11	64.0	36.0	228	57.0	43.0
Musculocutaneous	22	86.4	13.6	0.0	..	....	....	11	36.4	63.6	..	....	....	....	..	....	....	..	....	....	..	....	....	..	....	....	33	82.0	18.0
Axillary	16	81.2	8.8	0.0	..	....	....	4	25.0	75.0	..	....	....	....	..	....	....	..	....	....	..	....	....	..	....	....	18	78.6	21.4
Suprascapular	8	87.5	12.5	0.0																									
Thoracodorsalis	8	100.0	00.0	0.0																									
Subscapular	8	100.0	00.0	0.0																									
Long thoracic	6	50.0	50.0	0.0																									
Sciatic	44	34.0	60.0	6.0	17	100.0	00.0	....	....	....	21	4.8	53.4	42.8	5	20.0	40.0	18	38.9	61.1	10	20.0	80.0	6	83.0	17.0	121	70.0	30.0
Peroneal	16	62.5	31.3	6.2	20	80.0	20.0	89	16.9	83.1	9	22.2	44.4	33.4	5	60.0	80.0	6	00.0	100.0	..	....	....	7	57.0	43.0	152	38.0	62.0
Tibialis	10	60.0	40.0	0.0	4	75.0	25.0	38	39.5	60.5	2	00.0	100.0	00.0	..	....	....	1	100.0	00.0	..	....	....	2	00.0	100.0	67	46.0	54.0
Femoral	2	00.0	100.0	0.0																									
Inf. gluteal	1	100.0	00.0	0.0																									

No. = Number of cases
S = Success
I = Improved
F = Failures

is regenerating. The very large area of overlap of protopathic sensibility in median nerve lesions makes it possible to misinterpret this for regeneration.

Table VI indicates the reported results in the various nerves.

In addition to this, Tables VII to XII may be added:

TABLE VII
RESULTS OF NERVE SUTURES UPON INDIVIDUAL NERVES (DANE)

Nerve	Perfect	Good	Fair	Bad	Total
Ulnar	5	7	5	6	23
Median	3	1	8	2	14
Radial	3	2	4	3	12
Sciatic	3	3	1	6	13
Musculocutaneous	0	0	0	1	1

TABLE VIII
RESULTS OF NERVE SUTURES UPON INDIVIDUAL NERVES (DELAGÉNIÈRE)

Nerve	Number of Cases	Complete Success	Partial Success	Failures
Radial	47	37 (82.9%)	7 (14.89%)	3 (6.34%)
Ulnar	23	19 (82.6%)	3 (13.04%)	1 (4.34%)
Median	15	13 (86.66%)	2 (13.33%)	0
Musculocutaneous	5	5 (100%)	0	0
Brachial plexus	2	1 (50%)	1 (50%)	0
Sciatic nerve trunk	25	23 (92%)	2 (8%)	0
Peroneal	15	14 (93.33%)	1 (6.66%)	0
Tibial	4	4 (100%)	0	0
Posterior tibial	6	6 (100%)	0	0
Total	142	122 (85.91%)	16 (11.26%)	4 (2.81%)

TABLE IX
RESULTS OF NERVE SUTURES UPON INDIVIDUAL NERVES (FORRESTER-BROWN)

Median (35) 50% comp. motor; 28% comp. sensory
Ulnar (53) 17% comp. motor; 13% comp. sensory
66% incomplete of both
Radial (21) 62% comp. motor; 33% comp. sensory

TABLE X

RESULTS OF NERVE SUTURES UPON INDIVIDUAL NERVES (PLATT)

	Total	Proximal Muscles Only	Proximal and Distal (Incomplete)	Proximal and Distal (Total)	Distal Alone	Associated Sensory Recovery	Sensory Recovery Alone	Number of Recoveries	Failures
Radial	35	10	11	5	..	all		26	9
Median—									
Upper arm	10	7	3			in 5		10	nil
Forearm	20	3			6	in 6	8	17	3
Ulnar—									
Upper arm	27	19	3		1	in 14	1	24	3
Forearm	20				10	in 14	7	17	3
Sciatic—									
Trunk	21	16	nil	nil		in all		16	5
Segmental	4	2	nil	nil		in all		2	2
Peroneal	9	4	nil			in all		4	5
Posterior interosseus	1							nil	1
Plexus	3	2				2		2	1

Recoveries 118 = 79 per cent
Failures 32 = 21.3 per cent

TABLE XI

RESULTS OF NERVE SUTURES UPON INDIVIDUAL NERVES (STOPFORD)

Nerve	Cases	Failures	No Evidence of Recovery after Six Months
Radial	58	8	
Median	96	7	9
Ulnar	36	8	2
Sciatic	31	3	2
Peroneal	22	5	4
Tibial	2	0	0

TABLE XII
RESULTS OF NERVE SUTURES UPON INDIVIDUAL NERVES (POLLOCK-DAVIS)

Nerve	No Recovery after Three Months	Beginning Recovery after Three Months
Median	6	4
Ulnar	6	3
Peroneal	7	7
Sciatic	5	2
Radial	11	10
Ulnar and median	7	5

LEVEL OF THE LESION

The distance of the injury from the distal extremity of the limb seems to be an important factor in determining the time of recovery. Foerster makes the following notes relative to this:

	Months
Median—ulnar: lesions in axilla	12
lower third forearm	3
Sciatic: in gluteal region	9–11
just above knee joint	4– 6
Radial: in plexus—sup. longus recovery	12.4
level of lat. dorsi insertion	8
lower third arm	3

Platt notes that after suture of the radial nerve in the upper, middle and lower third of the arm return of power may be manifested in the supinator longus at about the seventh, sixth and fourth month respectively. Stracker was unable to find recovery in the distal muscles supplied by the radial, median or ulnar nerves irrespective of the level of the suture before one year had elapsed. He felt that in general sutures below the origin of the proximal muscle branches gave bad results. Platt believes that if the results of suture of the median and ulnar nerves in the upper arm or forearm be compared as regards distal recovery alone the quantitative recovery appears to be roughly equal in each case. Stopford is of the opinion that a nerve fiber regenerates more rapidly

TABLE XIII

RATE OF RECOVERY OF INDIVIDUAL MUSCLES (FOERSTER)

(Radial Nerve Lesion in the Axilla)

	Months
Long head triceps	3
Lower median head triceps	4
Supinator longus	6
Extensor carpi rad. long	8
Supinator brevis	13
Extensor carpi rad. brev	13
Extensor digiti comm	14
Abductor pollicis longus	15
Extensor carpi ulnaris	16
Extensor pollicis longus	17
Extensor pollicis brevis	19
Extensor indicus proprius	19

(Median Nerve Lesion in the Middle of the Arm)

	Months
Pronator teres	4
Palmaris longus	6
Flexor carpi rad	10
Flexor digiti sub	6
Flexor digiti prop	12
Flexor poll. long	12
Opponens long	18
Flexor poll. brevis	18
Abductor poll. brevis	22

(Ulnar Nerve Lesion in the Lower Third of the Arm)

	Months
Flexor carpi ulnaris	3
Flexor digiti prop	5
Adductor pollicis	13
Interossei	16

(Peroneal Nerve Lesion about the Knee Joint)

	Months
Peroneus longus	6
Peroneus brevis	9
Extensor dig. longus	9
Tibialis anticus	13
Extensor hallucis	19

(Tibial Nerve Lesion about the Knee Joint)

	Months
Gastrocnemius	5
Soleus	5
Tibialis posticus	8
Flexor digit. longus	15
Flexor hallucis longus	15
Plantar muscles	24

and readily the nearer the suture has been made to its anterior corneal cells. Although the example above of the spinator longus does not support this, some other muscles in his records of radial and median nerves do.

As has already been observed under the individual nerves, the order of recovery of muscles in injuries of the various nerves is reported in a varying manner by different observers. Foerster's observations upon his large number of cases are exceedingly valuable in this respect and the conclusions are noted in Table XIII.

Time of Recovery

Reports of immediate and very early regeneration may be interpreted as due to errors of interpretation of supplementary motility and sensory overlap. Foerster noted the following time for the various nerves observed by him:

TABLE XIV
TIME OF BEGINNING OF RECOVERY AFTER NERVE SUTURE (FOERSTER)

Nerve	Complete Section	
	Beginning of Recovery (Months)	Latest Beginning of Recovery (Months)
Radial	4.2	11
Median	3.2	9
Ulnar	3.5	9
Musculocutaneous	3.8	7
Axillary	4.0	9
Peroneal	6.5	12
Tibial	4.1	8
Sciatic	7.0	16

End Results

The final result may fall short of perfect recovery although regeneration may have started and progressed satisfactorily for a time. In lesions of the radial nerve, although all of the muscles may have recovered function, individual movements of extension of the proximal phalanges may remain faulty.

The small hand muscles in ulnar and median nerve lesions are often imperfectly recovered and the movements remain clumsy and inaccurate. At times this is due to imperfect sensory regeneration, especially of the fibers which carry deep sensibility.

Neurolysis

A considerable number of neurolyses and hersage have been performed. There is some difference of opinion as to the indication for this surgical procedure. Although recovery occurred in a relatively large percentage of cases, the question arises as to whether it would have occurred had the neurolysis not been performed. Athanasio-Bénisty reports upon 50 "simple freeings," performed by Gosset and Pascolis, with 20 complete cures and only one failure. Hersage performed upon 50 to 60 cases resulted in 25 recoveries and only one failure. She says, however, "It is a question whether operations of this kind are essential. Thus, an injured nerve which has not suffered severe cicatricial damage and has maintained its continuity will probably be able to regenerate at the end of eight to twelve months without an operation of any kind." In regard to the time element of this question, it may be stated definitely that although it was found that severely injured nerves began their recovery, and regeneration proceeded much as if the nerve had been sutured, a large number showed little regeneration twelve months following injury. Platt likewise believed that although in his 80 cases there was improvement in 75 per cent, it has been impossible to prove that the operation alone has determined this.

Foerster performed neurolysis 194 times and followed 188 of his cases. He reports a successful recovery in 77.2 per cent; 2.7 improved and 21 per cent failures.

In our small material of 39 cases of neurolysis, 35 were examined after two months. Of these, 27, or 73 per cent, showed continued regeneration.

TABLE XV
RESULTS OF NEUROLYSIS (AFTER FOERSTER)

	Cases	Successful Results (Per Cent)
Mauss and Kruger	35	80.0
Kunzel	23	65.2
Stoffel	48	68.7
Pelz	36	55.5
Moro	11	100.0
Stracker	91	83.5
Borchardt	30	80.0
Wexberg	59	81.3
Ranzi	33	76.0
Ranschburg	405	37.2
Perthes	49	69.4
Lehmann	46	54.5

NERVE TRANSPLANTS

In general, transplants were not followed by the degree of regeneration which we were led to believe would occur as the result of animal experimentation. In our own material regeneration was seen to have begun in 2 of 7 cases of radial nerve injury. The cases of injury to other nerves were observed too short a time after operation to permit of any conclusion.

TABLE XVI
RESULTS OF AUTOTRANSPLANTS (FOERSTER)
(21 Cases)

Radial Nerve (5)	1 success (25 months); 1 improved (8 months) 2 improved (11 months); 1 failure (10 months)
Median Nerve (4)	1 success (14 months) 1 improved (12 months)
Ulnar Nerve (11)	2 success (5–6 months) 8 improved (2 months)
Axillary Nerve (1)	success (28 months)

The results of homoplastic and heterotransplants in Foerster's hands were all bad. Gosset and Chairier analyzed

216 cases of nerve grafts. Only 5 good results were seen in the autografts; 2 in homografts; and 5 in heterografts.

A few successes were reported by Senient, Joyce, Forrester-Brown and others. Platt reported 18 "bridge operations" with complete failures. He had occasion to re-operate upon 6 cases, and Stopford examined 7 additional cases, all of which had shown failure of recovery. Platt was unable to confirm the presence of hypertrophy of the grafts described by various observers (Joyce, Lewis, Forrester-Brown). He unhesitatingly condemns the use of nerve grafts. It is to be noted that in England the use of single cutaneous grafts, and not cable transplants, had been the practice. We must await further observations on a large material of cable transplants of large size to confirm the results of a few observers before any final conclusion can be reached as to the efficacy of this operation.

[*The End*]

THIS MONTH'S CONTRIBUTORS

ABBOTT, WALTER D., M.D., Des Moines, Ia.
Neurol. Surg., Mercy, Methodist, Lutheran & Broadlawns Gen. Hosp.

AL-AKL, F. M., M.D., N. Y.
Head, Med. Unit, Lamb Exped. to N. Tibet.

ARN, ELMER R., M.D., F.A.C.S., Dayton, O.
Surg., Dayton Clin., Miami Valley Hosp. & Nat. Milit. Home.

BELT, NORVELL, M.D., Washington.
Clin. Instruc., Urol., Geo. Washington Univ. Med. Sch.; Attend. Urol., Garfield Mem. Hosp.; Urol., Episcopal Hosp.

CORYLLOS, POL. N., M.D., F.A.C.S., N. Y.
Prof. Clin. Surg. & Assoc. in Surg. Res., Cornell Med. Coll.; Attend. Thor. Surg., Metropolitan & Sea View Hosp.; Cons. Thor. Surg., N.V.A. Sanat. (Saranac Lake), Staten Island Hosp. (Staten Island) & Ulster Co. Tuber. Hosp. (Kingston).

DAVIS, LOYAL, M.D., PH.D., F.A.C.S., Chicago.
Assoc. Prof. Surg., Northwestern Univ. Med. School; Attend. Neurol. Surg., Passavant Mem., Michael Reese & Wesley Mem. Hosp.; Cons. Neurol. Surg., Edw. Hines Jr. & Mem. Hosp.

FLAGG, PALUEL J., M.D., N. Y.
Visit. Anes., Manhattan Eye & Ear, Hosp.; Anes., St. Vincent's, Fifth Ave. & Flower Hosp.; Cons. Anes., Jamaica, Mt. Vernon, St. Joseph's (Yonkers), Mary Immaculate, Flushing, St. Mary's (Far Rockaway) & Misericordia Hosp.; Author: "Anesthesia," Ed. 5, Phila., 1932.

FULD, JOSEPH E., M.D., N.Y.
Visit. Surg., City Hosp.

GOLDSCHMIDT, ERNST F., PH.D., DR.JUR., New Haven, Conn.
Res. Fellow, Dept. Surg., Yale Univ. Sch. Med.; Co-author: "The Heart Rate," Springfield, Ill., 1932.

GREELEY, PAUL W., M.D., Winnetka, Ill.
Clin. Assist. Surg., Northwestern Univ. Med. School, Chicago.

HARVEY, SAMUEL C., M.D., PH.B., F.A.C.S., New Haven, Conn.
Prof. Surg., Yale Univ. Sch. Med.; Surg.-in-Chief, New Haven Hosp. & Disp.

KANTER, AARON E., M.D., Chicago.
Assoc. Prof. Obst. & Gynec., Rush Med. Coll.; Att. Gynec., Cook Co., Mt. Sinai & No. Chicago Hosp.; Assoc. Att. Obst. & Gynec., Presbyterian Hosp.

KLAWANS, ARTHUR H., M.D., Chicago.
Clin. Assoc. Obst. & Gynec., Rush Med. Coll.; Assoc. Gynec., Cook Co. Hosp.; Adj. Gynec., Mt. Sinai Hosp.

KRETSCHMER, HERMAN L., M.D., F.A.C.S., Chicago.
Clin. Prof. G.-U. Surg., Rush Med. Coll., Univ. of Chicago; Urol., Presbyterian & Children's Mem. Hosp.

LOWRY, NELSON H., M.D., F.A.C.S., Chicago.
Attend. Surg., Edgewater & No. Chicago Hosp.; Cons. Surg., Ill. Masonic Hosp.

MCKNIGHT, R. B., M.D., F.A.C.S., Charlotte, N. C.
Surg., Mercy, Presbyterian & St. Peter's Hosp.; Assoc. Ed., *Southern Surg.*

MCLEAN, A. J., M.D., Portland, Ore.
Instruc. Surg. & Neuropathol., Univ. Ore. Med. Sch.; Neurosurg., Multnomah Co. Hosp.; Staff Mem., Good Samaritan Hosp.; Assoc. Staff Mem., Emanuel Hosp.

MOORE, SHERWOOD, M.D., St. Louis, Mo.
Prof. Radiol., Washington Univ. Sch. Med.; Direc., Edw. Mallinckrodt Inst. Radiol.

NIXON, EDWIN A., M.D., PH.G., M.SC.(MED.), Seattle, Wash.
Fac., Univ. Wash., Nurses Train. Sch.; Staff, Harborview Hosp.

POLLOCK, LEWIS J., M.D., F.A.C.S., Chicago.
Prof. Nerv. & Ment. Dis., Northwestern Univ. Med. School; Attend. Neurol., Passavant Mem., Michael Reese & Wesley Mem. Hosp.

RANDALL, ALEXANDER, M.D., F.A.C.S., Phila.
Prof. Urol., Univ. Pa.

SAGEL, JACOB, M.D., Minneapolis, Minn.
Instruc. Radiol., Univ. Minn.

SHANDS, HARLEY R., M.D., F.A.C.S., Jackson, Miss.
Visit. Surg., Baptist Hosp.

SORENSON, S., M.D., Chicago.
Attend Surg., Winnsboro Sanit.

AUTHOR INDEX TO VOLUME XVIII

Abbott, Walter D, 460
Al-Akl, F. M., 129, 545
Alden, Eliot, 347
Alpers, Bernard J., 51
Alvarez, Walter C., 207
Anderson, Roger, 36
Arn, E. R., 541

Bates, Charles O., 58
Belt, Orvell, 540
Bick, Edgar M., 71
Browder, Jefferson, 100

Caylor, Harold D., 62
Christopher, Frederick, 16
Coryllos, Pol. N., 494
Crabtree, E. Granville, 251

Daniel, William H., 323
Davis, Loyal, 151, 361, 553

Ebeling, W. W., 272
Ernsberger, G. H., 322

Flagge, Paluel W., 343, 542
Fray, Walter W., 124
Fuld, Joseph E., 514
Furniss, H. Dawson, 344

Goldberg, Leo G., 283
Goldschmidt, Ernst E., 467
Graham, A. Stephens, 135
Greeley, Paul W., 456

Harrow, Reed, 51
Harvey, Samuel C., 467
Hawley, George W., 19
Hill, Luther L., Jr., 303
Hill, William T., 124
Hinton, J. William, 292
Horrax, Gilbert, 1

Jelsma, Franklin, 76
Jennings, W. Kenneth, 16
Johnson, Clarence A., 324

Kanter, Aaron E., 529
Klawans, Arthur H., 529
Kleinberg, Samuel, 64
Kretschmer, Herman L., 478
Kroger, William P., 99

Laskey, Norman F., 259
Lichtenstein, Manuel E., 90
Lowry, Nelson H., 521

McLean, A. J., 417
McNealy, R. W., 90, 267
McKnight, R. B., 538
Mahoney, Louis E., 97
Mazer, Charles, 332
Mendenhall, A. M., 270
Mettenheiter, M. W., 337
Moore, Sherwood, 403
Moore, Veranus, 349

Narat, Joseph K., 130
Nixon, Edwin A., 442

Orr, Thomas G., 279

Patterson, George H., 88
Pollock, Lewis J., 151, 361, 553

Randall, Alexander, 482
Reed, Jewitt V., 285

Sacher, Clarence B., 82
Sagel, Jacob, 507
Schneider, Edwin H., 85
Shands, H. R., 510
Shapiro, Harold, 103
Smithies, Frank, 232
Sorenson, S., 521
Spurling, R. Glen, 76
Stanton, E. MacD., 246
Stevens, A. R., 296

de Takats, Geza, 26
de Tarnowsky, George, 261

Vale, C. Fremont, 103
Van Zwalenburg, C., 104, 133

Watson, William L., 113
Weiner, Samuel I., 123
Welton, T. S., 134, 348, 544
Wheeler, Philip H., 341
Willems, J. D., 267
Wood, Harold B., 31

Ziserman, A. J., 332

SUBJECT INDEX TO VOLUME XVIII

(B.B.) = Bookshelf Browsing. (Bi.B.) = Biographical Brevities. (C.) = Correspondence. (E.) = Editorial.

Abdominal pregnancy, advanced, diagnosis of, 270
Aberrant endometrium, 303
Abscess, left frontal lobe, 88
Animal diseases: role of experiments on animals in treatment of disease (B.B.), 349
  experiments, role of, in treatment of disease: Control of animal diseases, (B.B.), 349
  modern surgery (B.B.), 135
Appendicitis, acute, operative mortality of, 16
  tetanus following, 99
Arthritides, chronic, peripheral vascular system in, 71
Asphyxial death—a professional disgrace (E.), 542

Bag, colostomy, comfortable and sanitary, 541
Balance, water and chemical, in surgery, 279
Bile duct, common, non-traumatic perforation of, 103
Biographical Brevities:
  John Lovell, 134
  John Redman Coxe, 348
  Thomas Cadwalader, 544
Blood vessel ligation technique, 123
Bone, malignant disease of, discussion of diagnosis and *x*-ray treatment of, 403
Bones, sesamoid, fracture of, 507
Book Reviews:
  American illustrated medical dictionary (Dorland), 147
  Anatomy of human orbit and accessory organs of vision (Whitnall), 150
  Arteriographie des membres et de l'aorta abdominale (Dos Santos), 358
  Atlas der Röntgenstereoscopie (Cohn), 146
  Cardiac output of man in health and disease (Grollman), 551
  Causation of chronic gastroduodenal ulcers; a new theory (Spira), 148
  Classic descriptions of disease (Major), 358
  Curative values of light (Mayer), 551
  Descriptive atlas of radiographs (Bertwistle), 359
  Diatetik bei chirurgischen Erkrankungen (Lapp and Neuffer), 146
  Diseases of spinal cord (Cadwalader), 360
  Endocrine medicine (Engelbach), 360
  Fungous diseases (Jacobson), 359
  Grosse Arzte: Ein Geschichte der Heilkunde in Lebensbildern (Sigerist), 146
  Handbuch der gesamten Unfallheilkunde (Konig and Magnus), 359
  How to live (Fisher and Fisk), 358
  Individuality of blood in biology and in clinical and forensic medicine (Lattes), 359
  Kosmetische operationen (Eitner), 359
  Lectures on endocrinology (Timme), 147
  Livre d'or à l'occasion du jubilé de vingt-cinq ans d'activité chirurgicale du docteur Theodore L. Papayoannou, 359
  Medical electricity for students (Browne), 149
  Men against death (de Kruif), 551
  Mesenteric lymphadenitis (Strombeck), 359
  Minor surgery (Christopher), 148
  Pharmacology of medicinal agents in common use (Coulter), 148
  Principles of orthopedic surgery for nurses (Sever), 360
  Recent advances in anaesthesia and analgesia (Hewer), 149
  Reconstruction of biliary tract (Horgan), 146
Book Reviews:
  Text-book of anatomy and physiology (Williams), 147
  Thousand marriages (Dickinson and Beam), 551
  Use of lipiodol in diagnosis and treatment (Sicard and Forestier), 147
Books Received, 150
Bookshelf Browsing:
  Bound feet in China, 545
  Control of animal diseases, 349
  Modern surgery, 135
Breast, primary tuberculosis of, 97
Brunet-Flagge needle drier, 343

Cadwalader, Thomas (Bi.B.), 544
Calculi, urinary, prevention of recurrence of, 482
Cancer, statistics, reliability of, 31
Carcinoma of penis, 283
Carotid body, probable bilateral tumor of, 261
Cassette, multiple film, with grating localizer, 124
Chemical and water balance in surgery, 279
China, bound feet in (B.B.), 545
Cholesteatoma originating in skull bones causing symptoms of intracranial pressure, 51
Clinic, laboratory and, light from, on causes of peptic ulcer, 207
Colostomy bag, comfortable and sanitary, 541
Common bile duct, non-traumatic perforation of, 103
Constitutions, pathological (E.), 130
Corpus luteum, rupture of, 538
Correspondence:
  Fire buckets of Dr. John Fleet, 347
  Oxygen lack in hydraulic vicious circle, 133
Countertraction, well-leg method, 36
Coxe, John Redman (Bi.B.), 348
Cranial defects, repair of, 285
Current, electrosurgical, characteristics of adequate, 417
Cystostomy, suprapubic, simple method of, 540

Death, asphyxial, a professional disgrace (E.), 542
Defects, cranial, repair of, 285
Diagnosis of rectal tumors, common errors in, 323
  and *x*-ray treatment of malignant disease of bone, 403
Diet, salt free, in treatment of surgical tuberculosis, 337

Economics, medical (E.), 345
Editorials:
  Asphyxial death—a professional disgrace, 542
  Medical economics, 345
  Pathological constitutions, 130
Electrosurgical current, characteristics of adequate, 417
Endometrium, aberrant, 303
Extremities, small foreign bodies in, 267
  vascular disorders of, sympathetic nerve surgery in, 76

Feet, bound, in China (B.B.), 545
Fetal peritonitis, acute intestinal obstruction due to, 322
Fibromyoma of rectum, 62
Fire buckets of Dr. John Fleet (C.), 347
Fleet, Dr. John, fire buckets of (C.), 347
Foreign bodies in extremities, small, 267

Fracture(s), occupational therapy in treatment of, 292
of sesamoid bones, 507
skeletal traction and pressure in treatment of, 442
therapy, end-to-end approximation and accurate reduction as a necessity in, 272
x-ray and orthopedic table, new, 19

Gall bladder, stoneless, 246
Gastritis, phlegmonous, 113
Gastrostomy, Spivack's method of, 521

Hallux valgus, os intermetatarseum and, 337
Head injuries and some of their complications, 1
Hernias, difficult, 514
postoperative, 90
Hip, reconstruction-arthroplasty operation for, 64
Hydraulic vicious circle as it develops in the intestine, 104
oxygen lack in (C.), 133
Hysterectomy, paresis and obstruction of jejunum secondary to, 85

Impulses, painful, do sympathetic nerves transmit? 100
Injuries, head, and some of their complications, 1
peripheral nerve, 151, 361, 553
Intestinal obstruction, acute, due to fetal peritonitis, 322
Intestine, hydraulic vicious circle as it develops in, 104
Intracranial pressure, cholesteatoma originating in skull bones causing symptoms of, 51

Jejunum, paresis and obstruction of, secondary to hysterectomy, 85

Laboratory and clinic, light from, on causes of peptic ulcer, 207
Leg ulcers, Wright method of treating, 510
Ligation technique, blood vessel, 123
Lovell, John (Bi.B.), 134

Malposition, uterine, improved method of operation for, 82
Medical economics (E.), 345
Method, simple, of suprapubic cystostomy, 540
Modern surgery: role of experiments on animals in treatment of disease (B.B.), 135
Mortality, operative, of acute appendicitis, 16

Needle drier, Brunet-Flagge, 343
Neoplasms, benign, of stomach, 324
Nephrectomy, advantages of uretero-intestinal anastomosis following, 296
Nerve injuries, peripheral, 151, 361, 553
surgery, sympathetic, in vascular disorders of extremities, 76
Nerves, sympathetic, do they transmit painful impulses? 100
Nervous system, sympathetic, surgery of, 460
New instruments, 343

Occupational therapy in treatment of fractures, 292
Obstruction, acute intestinal, due to fetal peritonitis, 322
of jejunum, paresis and, secondary to hysterectomy, 85
Operative mortality of acute appendicitis, 16
Orthopedic, fracture and *x*-ray table, new, 19
Os intermetatarseum and hallux valgus, 341
Ossification centers, multiple, of patella, 456
Oxygen lack in hydraulic vicious circle (C.), 133

Paresis and obstruction of jejunum secondary to hysterectomy, 85
Patella, multiple ossification centers of, 456
Pathological constitutions (E.), 130
Penis, carcinoma of, 283
Perforation of common bile duct, non-traumatic, 103
Peripheral nerve injuries, 151, 361, 553
vascular system in chronic arthritides, 71
Peritonitis, fetal, acute intestinal obstruction due to, 322
Phlegmonous gastritis, 113
Postoperative hernia, 90
Pregnancy, advanced abdominal, diagnosis of, 270
Prevention of recurrence of urinary calculi, 482
Prostatectomy, total perineal, for small prostate, 251
Prostatic hypertrophy, recurrent benign, 259
Pseudomenstruation in human female, 332
Pulmonary tuberculosis, present status of surgical treatment in, 494

Reconstruction—arthroplasty operation for hip, 64
Rectal administration of tribromethanol, 467
tumors, common errors in diagnosis of, 323
Rectum, fibromyoma of, 62
Repair of cranial defects, 285
Rupture of corpus luteum, 538

Salt free diet in treatment of surgical tuberculosis, 337
Sesamoid bones, fracture of, 507
Skeletal traction and pressure in treatment of fractures, 442
Skull bones, cholesteatoma originating in, causing symptoms of intracranial pressure, 51
Spivack's method of gastrostomy, 521
Sponge holder, Metropolitan Hospital, 129
Statistics, cancer, reliability of, 31
Sterilization, vaginal, 529
Stomach, benign neoplasms of, 324
Stones, ureter, unusually large, 478
Suprapubic cystostomy, simple method of, 540
Surgery of sympathetic nervous system, 460
Surgical treatment in pulmonary tuberculosis, present status of, 494
Sympathetic nerve surgery in vascular disorders of extremities, 76
do they transmit painful impulses? 100
nervous system, surgery of, 460

Table, new fracture, *x*-ray and orthopedic, 19
Tetanus following acute appendicitis, 99
traumatic, treatment of, 58
Tourniquet, new, 344
Tribromethanol, rectal administration of, 467
Tuberculosis of breast, primary, 97
pulmonary, present status of surgical treatment in, 494
surgical, salt free diet in treatment of, 337
Tumor of carotid body, probable bilateral, 261
rectal, common errors in diagnosis of, 323

Ulcers, leg, Wright method of treating, 510
peptic, light from laboratory and clinic on causes of, 207
non-surgical treatment of, 232
Ureter stones, unusually large, 478
Uretero-intestinal anastomosis, advantages of, following nephrectomy, 296
Urinary calculi, prevention of recurrence of, 482

Uterine malposition, improved method of operation for, 82

Vaginal, sterilization, 529
Varicose veins, problems in treatment of, 26
Vascular disorders of extremities, sympathetic nerve surgery in, 76
system, peripheral, in chronic arthritides, 71

Water and chemical balance in surgery, 279
Well-leg countertraction method, 36
Wright method of treating leg ulcers, 510

X-ray, fracture and orthopedic table, new, 19
treatment of malignant disease of bone, diagnosis and, 403